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ENERGY OF CONDITIONAL INSTABILITY[1]

By WALTER LITTWIN

[Flugwetterwarte, Danzig-Langfuhr, January 1936]

The investigations by Margules and by Shaw provide a theoretical foundation for the calculation of the energy of atmospheric instability associated with a given distribution of temperature and humidity:

By the tephigram of Shaw (**1**), the energy liberated through the ascent of a small element of air of density ρ in an unstable layer (density ρ'), is evaluated; the energy per unit mass is

$$E=\int g\left(\frac{\rho-\rho'}{\rho}\right)dz, \tag{1}$$

in which g is the acceleration of gravity and z the height. This evaluation, however, gives no information as to the source from which the released energy is derived; the distribution of temperature and humidity remains unchanged by the thermodynamic process on which the evaluation is based.

Margules (**2**) calculates the amount of energy freed when a readjustment takes place in an isolated mass of air that initially is in unstable equilibrium. The air is bounded laterally by rigid, nonconducting walls, and above by a weightless piston; the transition to a stable end state takes place through vertical restratification, whereby the piston is raised. Since no external energy is available all the released energy comes from within the closed system considered. Margules calculated, for both the initial unstable condition and the final stable condition, the amounts of potential, internal, and kinetic energy of which the entire energy content is composed, and thus obtains the source of the liberated energy. His fundamental equation is

$$(P+U)-(P'+U')=K+A,$$

where P, U, K respectively denote potential, internal, and kinetic energy, and A is external work.

The results of Margules have clearly shown that energy of instability determined by temperature distribution is of great importance for energy transformations in the atmosphere. Margules' calculations relate almost exclusively to dry air; the results of an extension to humid air differed only slightly from those for dry air. On the basis of these results of Margules, it has come to be generally thought in meteorology that energy of instability in the atmosphere depends essentially only on the temperature distribution, and not on the water vapor content.

From the tephigram, however, Shaw and Refsdal (**3**) have been led to a different conclusion. Refsdal has shown that energy of instability also frequently exists in an unsaturated humid atmosphere, even though the stratification is stable with respect to displacements of dry air. According to Shaw and Refsdal, energy of instability materializes from several temperature stratifications only in the presence of water vapor.

This difference arises from the difference between the thermodynamic processes which form the bases of the calculations by Margules and Refsdal. The writer here presents detailed calculations of energy transformations for processes so selected as to include the cases of both Margules and Refsdal. First, the calculations of Margules are extended to conditionally unstable stratifications, and thus the importance of water vapor for the supply of energy clearly shown. Next, the relation between the calculations by Shaw and Refsdal, of the energy for an isolated ascending element, to the calculation by Margules, of the total supply of energy throughout a large closed system, is shown.

ENERGY SUPPLY IN CONDITIONAL INSTABILITY

To extend the calculations by Margules to conditionally unstable stratifications, we may use essentially the same procedure: A portion of the atmosphere is isolated on all sides by rigid walls, and above by a weightless piston, and this closed system goes from a labile to a stable stratification without exchange of heat with the environment. The amounts of each of the forms of energy are calculated for the initial and the final states, whence from the energy balance one can then determine the source of the energy released during the transition.

In the following example the temperature and the humidity distributions are so selected that in the absence of condensation no energy can be released. Now, by taking account of condensation, however, it is found that energy is set free; and this condition must therefore be attributed entirely to the influence of the water vapor: The initial state is specified by the following values.

Surface pressure, $p_0=1000$ mb; pressure at the upper boundary, $p_h=700$ mb; surface temperature, $T_0=296.72°$; virtual temperature at the surface, $T_{0v}=300°$; humidity, 100 percent throughout. The density distribution is so selected that neutral equilibrium obtains as long as no condensation takes place anywhere in the system; that is, the virtual temperature, T_v, diminishes with the height, z, at the dry adiabatic rate. Accordingly, $T_v=T_{0v}-\gamma z$, where γ is the dry adiabatic gradient.

[1] Translated from the German by Charles M. Lennahan and Edgar W. Woolard.

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When condensation is initiated in this atmosphere by vertical motion, air ascending from below can rise to the upper boundary. The system can therefore undergo a transition to a stable state through vertical motions. The final stable state is one in which any element is in stable equilibrium with respect to an arbitrarily great vertical displacement.

In the present example, the transition to the final stable stratification takes place in the following manner. The lower half exchanges place with the upper half. The upper half sinks bodily; but in the ascending half the sequence of layers is reversed, so that the previously lowest elements, initially under the pressure 1000 mb, come to the upper boundary, at a pressure of 700 mb, the elements initially at pressure 900 mb come to pressure 800 mb, and so on. In the final state a lower unsaturated stratum extends from 1000 mb to 850 mb, and an upper supersaturated one from 850 to 700 mb. See figure 1 (plotted on the adiabatic chart of Stüve).

Potential energy.—For the distribution of virtual temperature here assumed, the potential energy P may be calculated in finite form. For any polytropic atmosphere:

$$P=\int gzdm=\int zdp=\frac{T_{0v}}{\gamma}\int_{p_0}^{p_h}\left[1-(p/p_0)^{\frac{R\gamma}{g}}\right]dp$$

$$=\frac{T_{0v}}{\gamma}(p_0-p_h)-\frac{T_{0v}}{\gamma\left(\frac{R\gamma}{g}+1\right)}\left[p_0-p_h(p_h/p_0)^{\frac{R\gamma}{g}}\right]$$

where R is the gas constant, and γ the lapse rate.

After the readjustment the air in the upper half contains condensed water in liquid form, as well as water vapor. The density of this air is equal to the sum of the densities of the air, water vapor, and liquid water, $\rho=\rho_L+\rho_D+\rho_W$; we may introduce a generalized virtual temperature, defined by $T_w=p/R\rho$, that is the temperature at which dry air would have the density ρ of the mixture at the same pressure.

In our example, the distribution of density in the final state is such that T_w in the *upper half* is almost constant. With sufficient accuracy for our purposes, it may be assumed exactly constant between levels of 25 mb pressure difference, and the potential energy of each stratum calculated as follows:

$$P=\int zdp=\int_{p_2}^{p_1}z_1dp+\frac{R}{g}\int_{p_2}^{p_1}T\log\,(p_1/p)dp$$

$$=z_1(p_1-p_2)-\frac{RT}{g}[p_1-p_2-p_2\log\,(p_1/p_2)].$$

In the *lower half* the virtual temperature, and hence the potential energy, remain *unchanged*. If we now calculate the total potential energy in the initial and the final states, we find it to be *greater* in the final state than in the initial; hence the temperature must be higher in the upper half after the readjustment, thus raising part of the mass to a higher level.

This result reveals a fundamental difference between readjustments in unstable dry and humid closed systems: In dry air, energy of instability can be liberated in a restratification only if by this restratification the potential energy is diminished. In humid air, however, energy of instability can also be freed, as this example shows, even though the potential energy in the end condition is greater than at the beginning. These facts are of great importance in connection with the deepening of cyclones.

Internal energy.—The internal energy U_1 of dry air at temperature T is

$$U_1=c_vT=c_pT-Jpv.$$

Here J is the mechanical equivalent of heat; and p, v are the pressure and volume at the temperature T. The "internal energy" is that energy which depends only on the temperature of the substance considered; the internal energy U_w of liquid water is accordingly equal to the heat content, $i=c_{wp}T$, diminished by the work of expansion during the change in volume from 0° C. to the temperature T:

$$U_w=i-Jp(v_{wt}-v_{wo}).$$

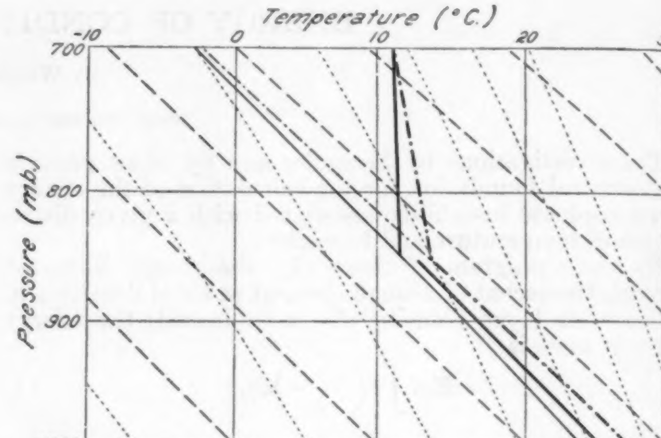

Fig. 1

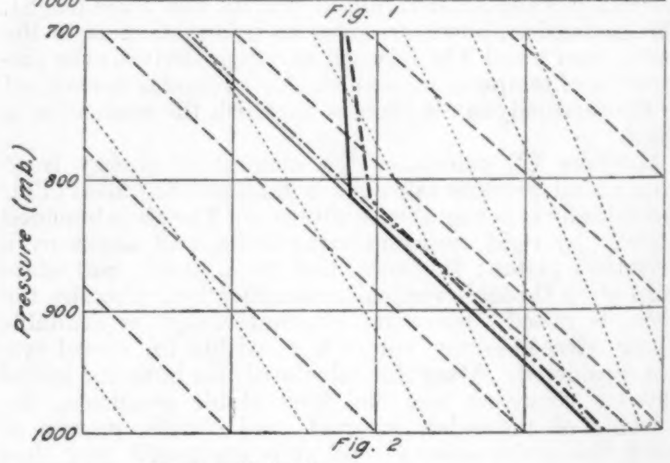

Fig. 2

Dry adiabats
Moist adiabats
Temp. before readjustment
Temp. after readjustment
Virtual temp. before adjustment
Virtual temp. after adjustment

The internal energy of water vapor is equal to the internal energy of the water, plus the internal heat of vaporization, which is the total heat of vaporization r, diminished by the work of expansion against the partial pressure of the water vapor during the transition from water to vapor:

$$U_d=U_w+r-Je(v_d-v_w),$$
$$=i-Jp(v_{wt}-v_{wo})+r-Je(v_d-v_w).$$

However, the quantities $Jp(v_{wt}-v_{wo})$ and Jev_w may be neglected, and $U_d=i+r-Jev_d$ taken as sufficiently accurate.

The above calculated internal energies are for one gram, and must be multiplied by the porportional weights of the

constituents in one gram of moist air, and then integrated over the entire layer, to find the total content of internal energy of the given system.

External work.—As the system is bounded laterally by rigid walls, work can be accomplished only at the upper surface when the piston is raised or lowered. The calculation shows that in our example the height of the layer from 1,000 to 700 mb is increased from 2,976.92 m to 3,012.90 m; the work done amounts to 700×35.98 m$\times$mb, or 251.86 joules.

Kinetic energy.—We assume, with Margules, that the system is at rest in the initial state, and that the liberated energy is converted into kinetic energy. We may now calculate the mean wind velocity which the liberated energy can generate in the system.

The results of the energy calculations are shown in table 1. It is apparent that only the water vapor furnishes energy. The complete energy balance is as follows:

		Joules
Liberated: Internal energy of water vapor		1, 186. 05
Consumed:		
Internal energy of air	857. 28	
Internal energy of water	22. 75	
Potential energy	17. 70	
Work	258. 86	
		1, 156. 59
Net release		29. 46

TABLE I

	Potential energy (Joules)	Internal energy (Joules)		
		Air	Water-vapor	Water
Initial	4, 274. 61	2, 411. 95	7, 624. 59	
Final	4, 292. 31	3, 269. 23	6, 438. 54	22. 75
Initial−final	−17. 70	−857. 28	+1, 186. 05	−22. 75

Assuming this amount of energy to be uniformly distributed throughout the mass of air, and to appear in the form of kinetic energy, the corresponding mean wind velocity is 13.9 m/sec. (50 km/hr.). The liberated energy comes exclusively from the internal energy of the water vapor.

In dry air the same amount of instability energy would exist if a super-adiabatic gradient of 1.15° C/100 m existed throughout the layer from 1,000 m to 700 m.

CALCULATION OF THE ENERGY SUPPLY WITH THE AID OF THE TEPHIGRAM

The usual type of calculation with the tephigram indicates whether energy of instability exists somewhere in the atmosphere and determines the amount which would be freed in the ascent of a small isolated mass of air. We cannot infer from it alone, however, the total energy that would be liberated in a complete readjustment of the system to stable equilibrium; it is necessary to represent the transition of the system as a result of separate steps, and apply the tephigram to each single step. In this procedure, account must be taken of the following three points, which are usually neglected:

(1) In any vertical readjustment, both ascent and descent must take place. The total mass moved is accordingly always about twice as great as that which ascends.

(2) The descending motions may increase or decrease the amount of liberated energy, according as the temperature gradient is greater than or less than the dry adiabatic.

(3) Every partial restratification alters the lapse-rate and the stability, and the system is brought one step nearer a stable state.

The energy in a closed system will now be calculated by both the tephigram and the method of Margules. The initial state selected is one in which the true temperature changes with the pressure at the dry adiabatic rate, the humidity is 70 percent throughout the system, the surface pressure is 1,000 mb, the pressure at the upper boundary is 700 mb, and the surface temperature is 298.2° A. or 25.0° C.

The final stable state is established by a complete overturn of the system: The air initially at the pressure 1,000 mb comes under the pressure 700 mb and vice versa; and correspondingly, there is an exchange between the other levels that is symmetric about the mean level. See figure 2.

For the purposes of calculation, the system is divided into twelve layers; and the transition to the final state is effected in six stages:

In the first step, the lowest stratum, from 1,000 to 975 mb, exchanges place with the layer from 725 to 700 mb, while the intermediate layers remain in their intial positions; in the second step, the layers from 975 to 950, and from 750 to 725 mb, exchange places; and so on. The energy released in each step is calculated by two methods.

1. The first method of calculation is the same as the one previously used in this paper. The calculation of the potential and the internal energy is repeated after each partial restratification, and an energy balance set up, from which it may be seen how much energy is liberated by this partial restratification, and where this energy has its source. The results are shown in table 2.

TABLE 2

Stage	Exchange	Energy released (Joules)	Energy (Joule/gr)	Velocity (m/sec.)
1	1,000...975⇄725...700	11. 12	0. 221	21. 1
2	975...950⇄750...725	6. 84	0. 134	16. 4
3	950...925⇄775...750	3. 80	0. 076	12. 6
4	925...900⇄800...775	1. 88	0. 037	8. 6
5	900...875⇄825...800	1. 00	0. 020	6. 3
6	875...850⇄850...825	0. 02	0. 0004	0. 9

Sum, 24.77; mean, 0.810→12.8 m/sec.

2. In the second calculation the tephigram is used; otherwise, the basis is the same as above.

The energy which by equation (1) will be freed in the ascent of the initially lowest element is evaluated in the usual way; in the present example, it amounts to 0.473 joule per gram. In the same way, for an element which sinks from pressure 700 to pressure 1,000 mb, the energy is 0.072 joule per gram. For the particles initially at pressures 975 and 725 mb, the amounts of energy released by the exchange of place are 0.293 and 0.053 joule per gram. Similar calculations are made at pressure steps of 25 mb.

From the values of the energy per gram, the mean values for the 25 mb strata are formed and combined into mean values for the successive stages; these may be compared with the values obtained from the first calculation above, and will be found to agree closely.

The total liberated energy is given by multiplying the value in joules per gram by the mass of air involved. See table 3.

The differences between the amounts of energy for the individual elements and strata are striking. It is not possible to infer the energy supply of an entire layer from

the calculated energy of instability for a particular element.

The first method of calculation leads to an exact energy balance, and shows the source of the liberated energy. The second method of calculation involves less numerical calculation, and gives separately the energy from the ascending and the descending air.

TABLE 3

Pressure (millibars) Initial	Pressure (millibars) Final	Energy released (joule/gr)	Mean (joule/gr)	Mean energy of layer (joule/gr)	Mean velocity (m/sec)
1,000	700	0.473	0.272		
700	1,000	0.072			
				0.222	21.1
975	725	0.293	0.173		
725	975	0.053			
				0.134	16.4
950	750	0.156	0.096		
750	950	0.036			
				0.069	11.8
925	775	0.063	0.042		
775	925	0.021			
				0.028	7.5
900	800	0.017	0.014		
800	900	0.010			
				0.009	4.3
875	825	0.0028	0.003		
825	875	0.0029			
				0.0014	1.7
850	850	0.0	0.000		

APPLICABILITY OF THE TWO METHODS OF EVALUATION

We shall now consider the problem of which of the processes in the atmosphere correspond to the different methods of evaluation by the tephigram.

The usual method emphasizes the dynamical processes which involve the ascent of a small isolated mass of air; it yields the energy for this mass, but tells nothing about its source. This procedure is appropriate when the stratification of the system is not changed by the displacement of the element; each mass that ascends must be replaced by a mass with the same temperature and humidity, or else enough heat must be supplied to the system to maintain the temperature distribution unaltered (e. g., by continuous radiation). Conditions are most appropriate for the application of this method of evaluation when the vertical equilibrium in the atmosphere is conditionally unstable, but the temperature gradient less than the dry adiabatic; then the equilibrium is stable with respect to downward motion, and the process is one of strong ascending motions over small areas and slow downward motions over larger areas (4). The energy released will come largely from the ascending elements.

With gradients greater than the dry adiabatic, account must always be taken, even in dry air, of the energy contributions from descending air (5); these can be taken directly from the tephigram, which, therefore, always gives a good indication of the intensity of convection.

The other method of using the tephigram takes into account the changes in the vertical equilibrium brought about by the displacements of air, and should be used whenever the mass of air which ascends is so large that it spreads out into a layer of appreciable thickness. The vertical temperature distribution is then changed, in the absence of a supply of external energy; and the air which subsequently ascends meets with a different environment from that encountered by the previous ascending elements. This method is of fundamental importance to the quantitative determination of the energy of instability for an entire body of air, a knowledge of the amount of such energy is very desirable, because it is a numerical measure of the importance of the body of air for energy transformations in the atmosphere. When the tephigram is used only to calculate energy of instability for a single isolated ascending element, and this is erroneously considered an index to the total available energy, it is easy to overestimate the latter, because in an unstable equilibrium not all the air may ascend to the upper limit of the unstable region and frequently a part of the released energy is taken up by the downward moving air.

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(2) Max Margules, Uber die Energie der Stürme, *Jahrbuch der k. k. Zentralanstalt für Meteorologie*, Jahrgange 1903, Anhang, Wien 1905; trans. in Cleveland Abbe, *Mechanics of the Earth's Atmosphere* (3d collection), Washington, 1910. See F. M. Exner, *Dynamische Meteorologie*, Kap. 7; D. Brunt, *Physical and Dynamical Meteorology*, chap. XV.

(3) Anfinn Refsdal. Der feuchtlabile Niederschlag. *Geofysisker Publ.* 5. Nr. 12. Oslo 1930.

(4) P. Raethjen. Die Böenfront als fortschreitende Umlagerungswelle. *Met. Zeit.*, 51, 9–17. 1934.

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SYNOPTIC DETERMINATION AND FORECASTING SIGNIFICANCE OF COLD FRONTS ALOFT [1]

By B. HOLZMAN [2]

[Soil Conservation Service, Section of Climatic and Physiographic Research, Washington, D. C., December 1936]

Cold-front and warm-front types of occlusions [3] are common on the synoptic chart, but frequently the latter have been confused with the cold-front types. In synoptic analyses the boundaries of the various air masses have all too frequently been considered only from the viewpoint of surface representation, with the result that upper air cold fronts, although occasionally recognized, have generally been held unique. The concept of an upper cold front is by no means new [4]; and recently Wexler [5] has presented a detailed analysis of a warm-front type of occlusion.

Cold fronts almost invariably become upper-air fronts as a result of warm-front occlusions, although conceivably they may occasionally be generated by fields of frontogenesis with an influence confined to air masses aloft. The recognition of the warm-front type of occlusion and the upper cold front is of paramount significance to meteorologists. The origin of precipitation that occurs throughout the Great Plains in winter may often be directly attributed to an upper cold-front invasion. A forecast of ceilings, cloud layers, thunderstorms, zones of turbulence and icing conditions based upon the recognition of an upper cold front will have distinctive features of immediate pertinency to aircraft travel.

[1] Presented at the meeting of the American Meteorological Society, Kansas City, Missouri, June 1936.

[2] Formerly meteorologist—American Airlines, Inc., Newark, New Jersey.

[3] Bjerknes, et. al., *Physikalische Hydrodynamik*, p. 719. Berlin, 1933.

[4] Bjerknes, J. and Solberg, H. Life cycle of cyclones and the polar front theory of atmospheric circulation. *Nordske Videnskaps-Akademi Geofysiske Publikasjoner* vol. 3, no. 1, 1922.

[5] Wexler, H. Analysis of a warm-front type occlusion. MONTHLY WEATHER REVIEW, vol. 63, pp. 213–221, July 1935.

Warm-front occlusions always occur when the advancing wedge of air is of lesser density than the wedge upon which it encroaches. Thus in winter when the continent is colder than adjacent bodies of water, warm-front types of occlusions are prevalent along the western coast; and in summer, such occlusions will exhibit themselves on the eastern coast. However, occlusions are not necessarily confined to coast lines; and warm-front occlusions can be recognized over any part of continental or maritime areas whenever the densities of the air masses involved are appropriately related.

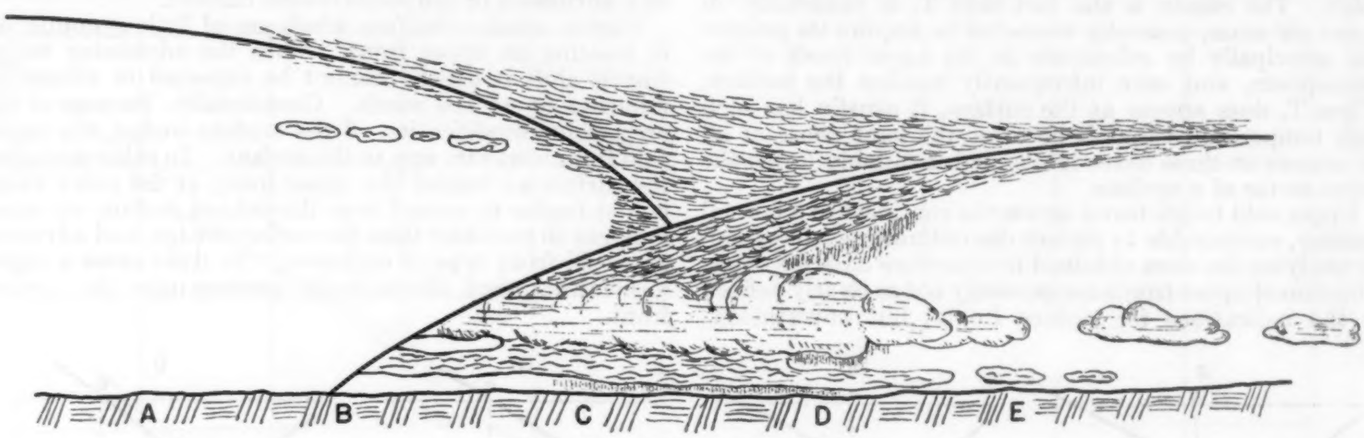


FIGURE 1.—Warm-front type of occlusion in winter.

Numerous upper cold fronts outlining invasions of P_M (Polar Maritime) air aloft have been noted throughout the Middle West; and although associated with no immediately apparent occlusion, the historic sequences nearly always indicate an origin from occluding cyclones either over the Pacific Ocean or along the western coast of the continent. After crossing the Rocky Mountains this type of upper cold front generally rides aloft over a dome of P_c (Polar Continental) air, and may cause a wave on the cold front of the surface air mass. As the wave develops and occlusion begins, the relative densities generally cause the new cyclone itself to proceed as a cold-front type of occlusion. However, it is possible for the wave to occlude in the warm front manner; and if this be the case, a rather complex situation of two upper cold fronts, one marking the invasion of P_M air that originally induced the wave on the surface air mass, and one arising from the occluding cyclone, can then be detected.

When extensive masses of fresh P_c air recurrently occupy the Great Plains area in winter, a wave that has no genetic relation to an upper front may develop on the Polar Front that usually extends through the Canadian provinces of Alberta or Saskatchewan. With the intensification of the cyclone and the subsequent occlusion process, an upper cold front, marking the advance of an old P_c air mass, occasionally can be found over the Dakotas and Nebraska. This is explained by the fact that Polar air advancing as a surface air mass from the Canadian provinces is sometimes of less density than the fresh P_c air lying to the southeast. It may appear very unlikely that Polar air occupying the central and eastern portions of the United States should have a greater density than air from Alberta or Saskatchewan; but it is to be recalled that the modification of an air mass depends upon its trajectory, and in a rapid advance of a dome of Polar air from high latitudes to the lower latitudes of the United States it is possible for an air mass to maintain sufficient density for a cyclone developed on its northwestern periphery to occlude in a warm front manner. This type of upper cold front will be encountered only in rare instances, however; the normal occlusion of these cyclones is of the cold-front type.

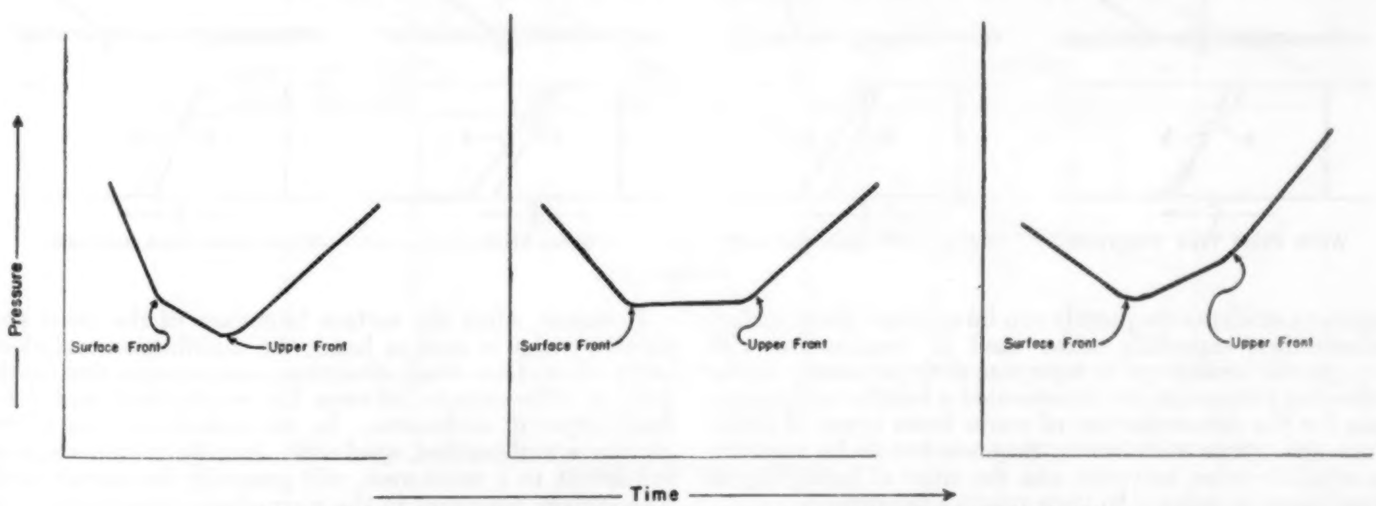


FIGURE 2.—Typical pressure traces during passage of an upper cold front with warm-front type of occlusion.

Willett [6] has called attention to the upper cold fronts that may exist between T_s (Tropical Superior) and T_G (Tropical Gulf) air masses. Either T_s or T_G may be the active air mass, depending upon which of the two air masses has the greater density. The development of the upper discontinuities between T_s and T_G does not originate from occluding cyclones as is generally the case for Polar air masses, but is instead probably caused by frontogenesis aloft brought about by properly oriented deformation fields. The reason is the fact that T_s is essentially an upper air mass, generally conceded to acquire its properties principally by subsidence in the upper levels of the atmosphere, and only infrequently reaches the surface. When T_s does appear at the surface, it usually has such high temperatures that it becomes the least dense of all air masses at these lower levels, and invariably forms the warm sector of a cyclone.

Upper cold fronts travel across the continent in a normal manner, comparable to surface discontinuities. In synoptic analyses the clues obtained from surface data for determination of upper fronts are generally not as clearly defined as the indications for surface fronts; but nevertheless, sufficient evidence frequently can be obtained from surface information, especially when used in conjunction with aerographic soundings, to recognize their presence. In the following paragraphs are enumerated a number of synoptic aids for the determination of warm front types of occlusions and upper cold fronts; they are not to be regarded as infallible rules, however, and the order of listing has no significance in respect to their relative importance.

Winds aloft.—Usually a well-marked discontinuity in the winds aloft separates the encroaching upper wedge from the air mass below. The winds in the surface air mass may be southwesterly, whereas aloft a vigorous shift to northwest will be encountered. In the various situations observed, this type of shift has most commonly accompanied the upper front. However, the discontinuity need not be indicated by a directional shift in wind; and many times a change in speed will be the only clue available. One is to be cautioned against attaching any particular significance to a mere change in direction of the winds aloft. In cases of over-running tropical air associated with a warm front, apparent directional discontinuities, actually in anticyclonic curvature of streamlines, are always encountered in the winds. As pointed out by Bjerknes [7] and others, a southwest current, during its ascent along a warm-front surface, may acquire considerable turning of its horizontal streamlines from the deflective effect of the earth's rotation; and aloft it will show as a northwest or north-northwest current.

Surface winds.—Surface winds are of little synoptic aid in locating an upper front. Since the advancing wedge travels aloft it usually cannot be expected to extend its influence to surface winds. Occasionally, because of the progressive modification of the surface wedge, the upper cold front works its way to the surface. In other instances the surface air behind the upper front, at the point where it first begins to ascend over the coldest surface air mass, happens to be colder than the surface wedge, and advances as a cold-front type of occlusion. In these cases a vigorous surface wind discontinuity accompanies the surface front.

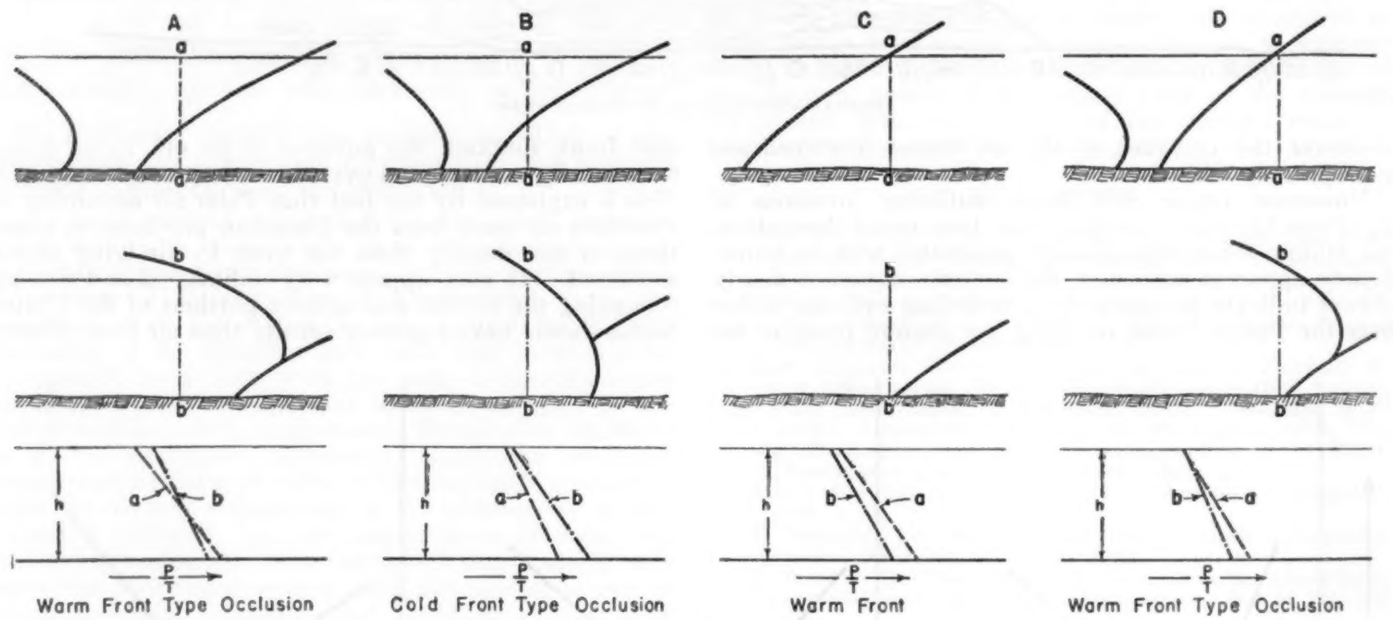


FIGURE 3.

However, when the surface boundary of the lower and passive wedge is near at hand, the distribution and character of surface wind directions and speeds frequently help to differentiate between the warm-front and cold-front types of occlusions. In the cold-front type of occlusion a well-marked wind shift, usually from a south or southwest to a northwest, will generally be encountered. The surface boundary in the warm-front type of occlusion will in contrast usually show a gradual shift from a southwest or west to a west-northwest or northwest, very similar to the shift that accompanies a warm front. Often a broad zone of winds having a slight southerly component shifting to a slight northerly component will mark the surface discontinuity of the passive wedge.

It should be pointed out that the location of the surface discontinuity in the warm-front type of occlusion frequently is of less significance in forecasting than the determination of the position of the upper cold front. Usually the chief importance of recognizing this surface

[6] Willett, H. C. Discussion and illustration of problems suggested by the analysis of atmospheric cross-sections. *Papers in Physical Oceanography and Meteorology Massachusetts Institute of Technology and Woods Hole Oceanographic Institution*, vol. 4, no. 2, July 1935.

[7] Bjerknes, J. Exploration de quelques perturbations atmosphériques à l'aide de sondages rapprochés dans le temps. *Norske Videnskaps-Akademi Geofysiske Publikasjoner*, vol. 9, no. 9, 1932.

boundary is to furnish indirect evidence of the presence of an upper cold front at some distance in advance of the shifting surface winds.

Pressure change characteristic.—The pressure change characteristic offers a very important clue to the presence of an upper front. The barometer trace during passage of a surface cold front will show falling, and then sharply rising, pressures; but the pressure change caused by the passage of an upper cold front is usually characterized by a lesser discontinuity—perhaps a slower rate of decrease either is not apparent or else has been left far behind the upper front, the barogram may exhibit only an ill-defined discontinuity, difficulty to distinguish from the normal diurnal pressure changes; but if a systematic linear arrangement of slight discontinuities in the pressure tendencies, unaccompanied by a surface wind shift, can be traced, this in itself is occasionally sufficient evidence to indicate the presence of an upper front.

Pressure trough.—In contrast to the generally distinct V-shaped isobars associated with a surface cold front, only

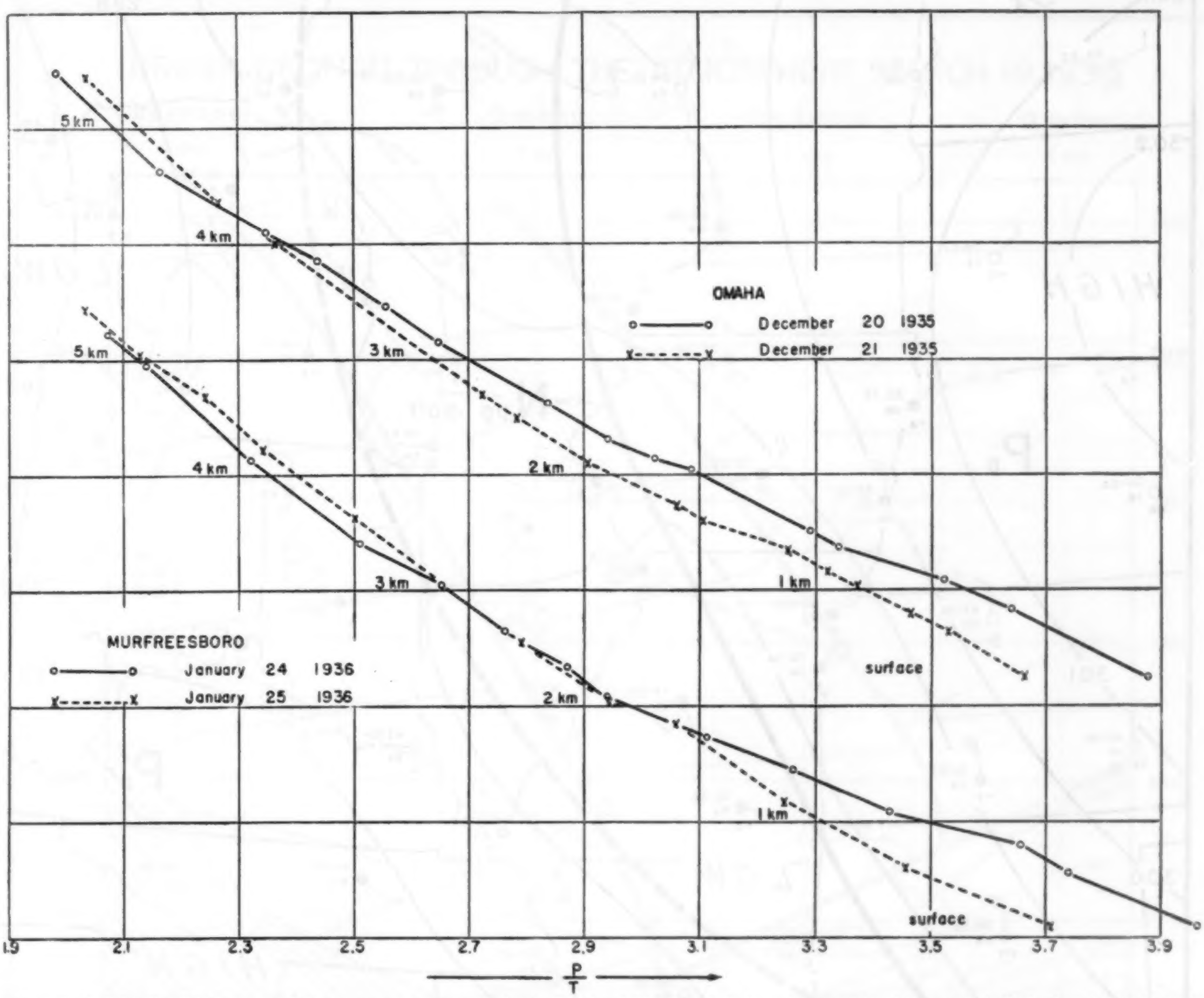


FIGURE 4.—Typical density-altitude curves during passages of upper cold fronts; P/T in mb/°A, altitude in km. The crossing of the curves indicates invasion by an air mass bounded by an upper cold front.

or only a slight rise in the barometer, followed by a steadily and rapidly rising pressure.

Thus in figure 1 the region CDE may have negative changes of from 4 to 6 hundredths of an inch in 3 hours. The region BC probably will exhibit negative changes of from 0 to 4 hundredths, since the advancing wedge aloft has the effect of compensating the falling pressures normally expected ahead of the surface front. The region AB is characterized by positive tendencies, generally 0 to 8 hundredths.

Typical pressure traces such as may be experienced at any one station are indicated in figure 2. Quite often, however, when the surface boundary of the lower wedge

minor and poorly defined surface pressure throughs characterize upper cold fronts. A sharp discontinuity in the isobars is not always associated with surface fronts—not in cases of frontolysis, e. g. (*Physikalische Hydrodynamik*, p. 727)—and no undue significance should be given a broad or narrow trough of pressure with more or less continuous isobars.

Although an upper front may be evidenced at the surface by a broad pressure trough, aloft it may be accompanied by a pronounced low pressure, and the gradient will be such as to cause a very significant increase in the winds at these levels as the front approaches. However, in the case of the warm-front type of occlusion, a minor

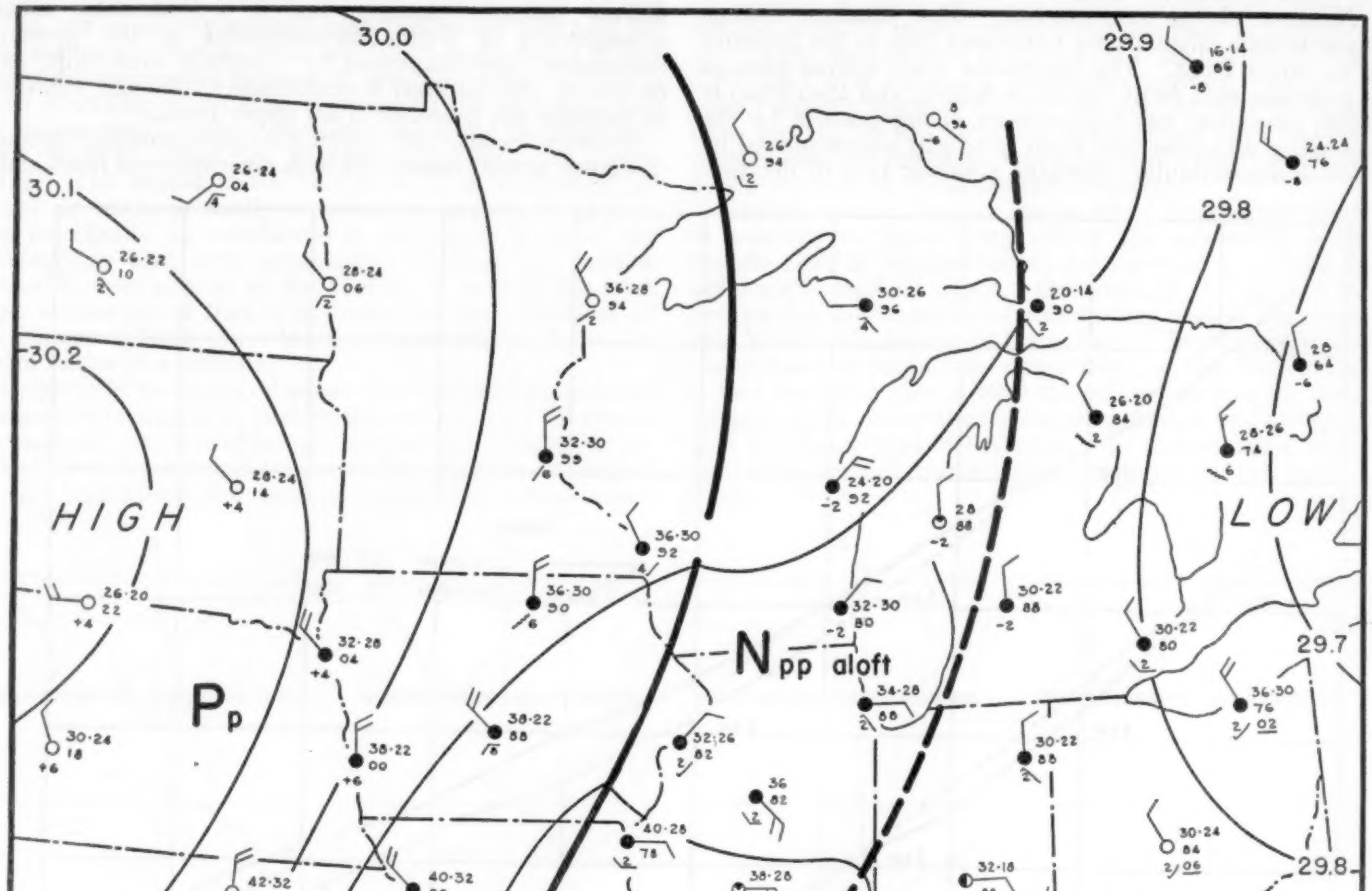


FIGURE 5.

surface trough in advance of the trough that accompanies the surface front is generally significant, and is good evidence for the presence of an upper front. Isobars should be drawn very carefully, avoiding too great a smoothing, as the minor trough can easily be obscured. Frequently it will be helpful if the isobars are drawn before attempting to locate the frontal discontinuities.

Cloud types and precipitation.—A characteristic feature of the warm-front type of occlusion is the frequent absence of cloud forms during the initial occluding process.

wind discontinuities, an anomalous belt of alto-cumulus may likewise indicate an upper cold front. Here again this evidence needs further substantiation, for a simple warm front may often show a zone of cloudiness separated from the surface wind discontinuity by a zone of clear skies.

Generally the most complex cloud systems that accompany warm-front type occlusions occur during winter. In the initial stage a belt of alto-cumulus or alto-stratus may be noticed in advance of the surface shift, and the

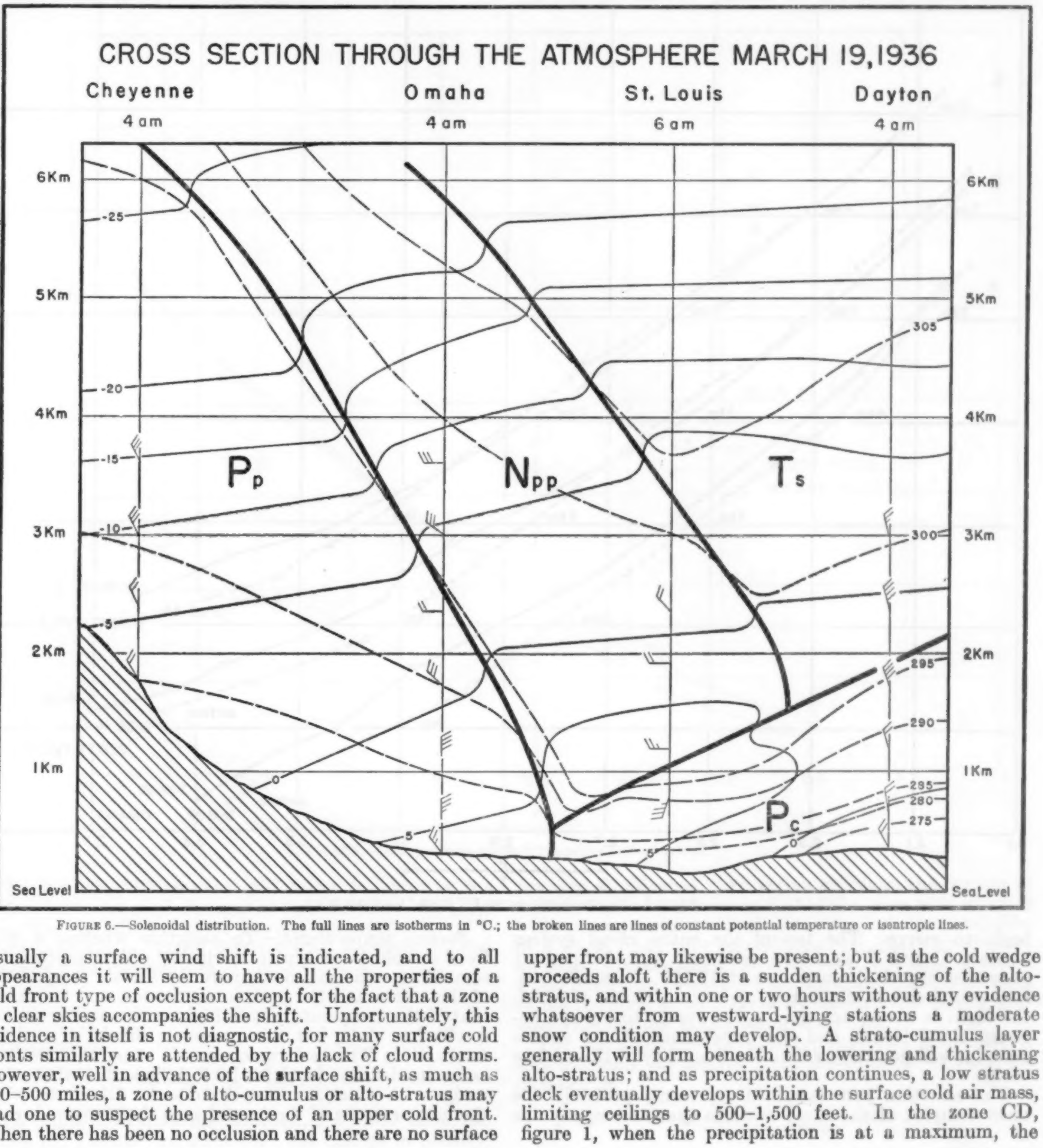


FIGURE 6.—Solenoidal distribution. The full lines are isotherms in °C.; the broken lines are lines of constant potential temperature or isentropic lines.

Usually a surface wind shift is indicated, and to all appearances it will seem to have all the properties of a cold front type of occlusion except for the fact that a zone of clear skies accompanies the shift. Unfortunately, this evidence in itself is not diagnostic, for many surface cold fronts similarly are attended by the lack of cloud forms. However, well in advance of the surface shift, as much as 100–500 miles, a zone of alto-cumulus or alto-stratus may lead one to suspect the presence of an upper cold front. When there has been no occlusion and there are no surface

upper front may likewise be present; but as the cold wedge proceeds aloft there is a sudden thickening of the alto-stratus, and within one or two hours without any evidence whatsoever from westward-lying stations a moderate snow condition may develop. A strato-cumulus layer generally will form beneath the lowering and thickening alto-stratus; and as precipitation continues, a low stratus deck eventually develops within the surface cold air mass, limiting ceilings to 500–1,500 feet. In the zone CD, figure 1, when the precipitation is at a maximum, the

various cloud decks generally merge together into a thick cloud system. Thus an airplane flight made from E to A would, upon ascension, encounter first a low stratus condition near 500 to 800 feet with a top near 1,500, and second the strato-cumulus deck which may extend from 2,000 to 8,000 feet. Between E and D the flight could be made above the strato-cumulus. The upper alto-stratus would be steadily and rapidly thickening; and precipitation, if not encountered upon ascent from E, would most certainly be encountered above D where the clouds decks begin to merge. The top of the entire cloud system between C and E would be extremely high for present passenger travel—it may exceed 17,000 or 18,000 feet. Between C and B, depending upon the altitude at which the flight is made, one may again expect to emerge between cloud layers, and the upper limit of the strato-cumulus will generally define the boundary of the surface wedge.

The situation just described represents probably the most complex of the cloud systems that accompany the upper cold front, and will rarely occur in any season other than winter. Usually a zone of alto-cumulus with little or no precipitation will mark the advance of an upper cold front in spring and autumn. In summer a series of high level thunderstorms, caused by the release of the convective instability of the tropical air which the upper wedge most commonly displaces, or in a few cases caused by the release of the instability of the air in the upper advancing wedge itself, will serve to locate the boundary of the active air mass.

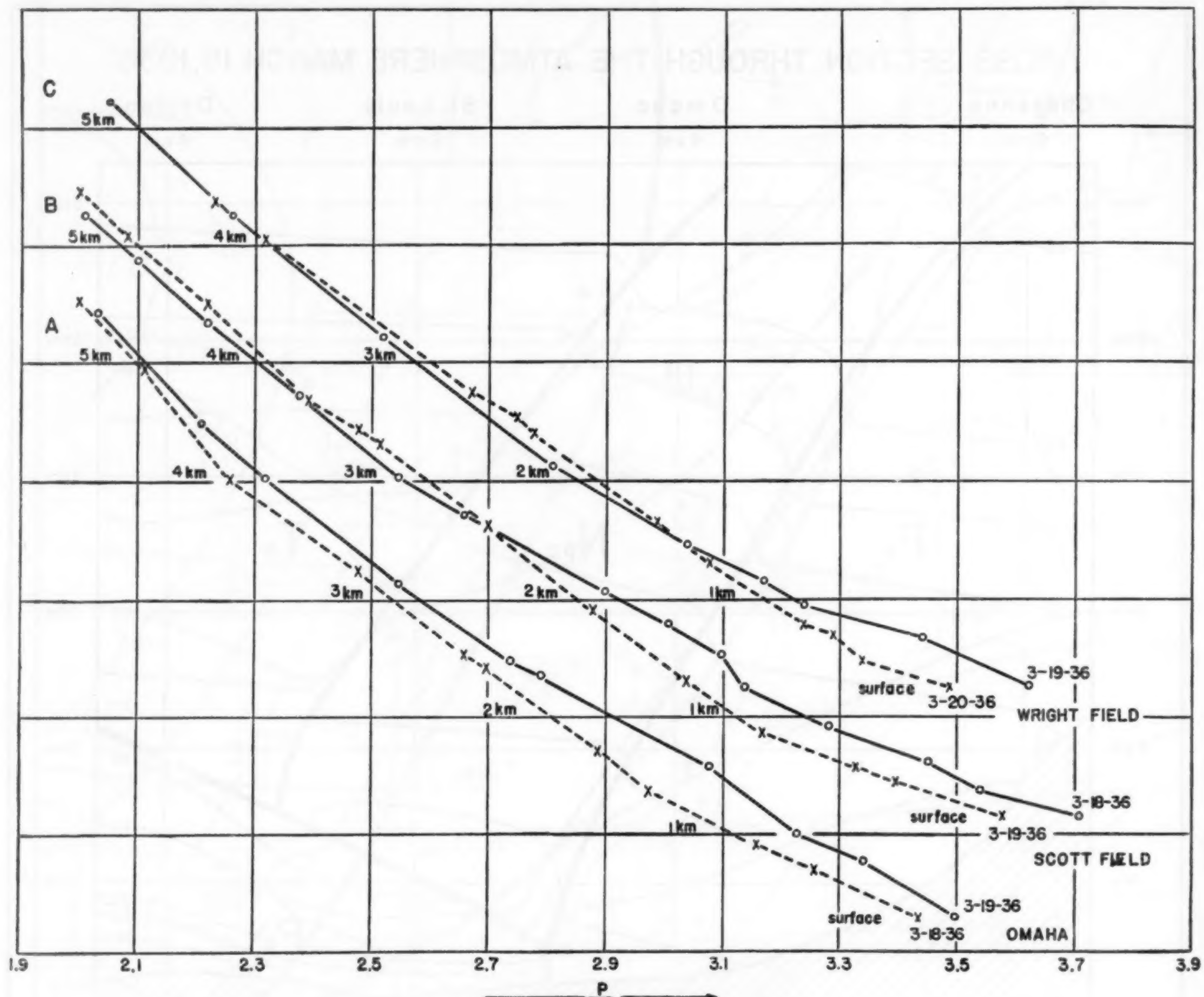


FIGURE 7.—Density-altitude curves; P/T in mb/°A, altitude in km.

Surface temperatures.—To ascertain whether a warm front or cold front type of occlusion will take place, it is sometimes sufficient to compare the surface temperatures of the active and the passive air masses, and to presume that if the temperatures are high in the active air mass it will flow aloft; but this procedure should be used with reservation: The real reason an air mass ascends is because its density, level for level, is less than that of the wedge with which it comes in contact. Of course, within the narrow limits of the frontal zone the pressure is essen-

tially the same in the cold and the warm mass, and the relative density is thus determined by temperature and to a slight extent also by the water vapor content. However, the distribution of meteorological stations does not allow a determination of density from temperatures alone, especially when comparisons for 12 or 24 hours are desirable. Likewise surface temperatures are easily influenced by insolation, radiation, evaporation, and condensation; and when employed for comparative purposes, in establishing the lesser or greater density of an air mass, should always be used in conjunction with the pressures.

$d\rho$, at the given level, produced by the increments in pressure and temperature, will be

$$d\rho=K\left[\frac{1}{30}-\frac{1}{30}\right]=0.$$

The danger of comparing densities by consideration only of temperatures is amply illustrated by this example in which a 3° increase in temperature produces no change in density.

Density.—In the synoptic determination of upper fronts, the densities of the various air masses involved are of primary significance. An active air mass, the density of which at each level exceeds that of the mass with which it will come in contact, will of course preclude the possibility of a warm front type of occlusion. A P_p (Polar Pacific) air mass, with a density, level for level, less than that of a P_c air mass then overlying the central and eastern portions of the country, must necessarily continue its march aloft after crossing the Rocky Mountain chain.

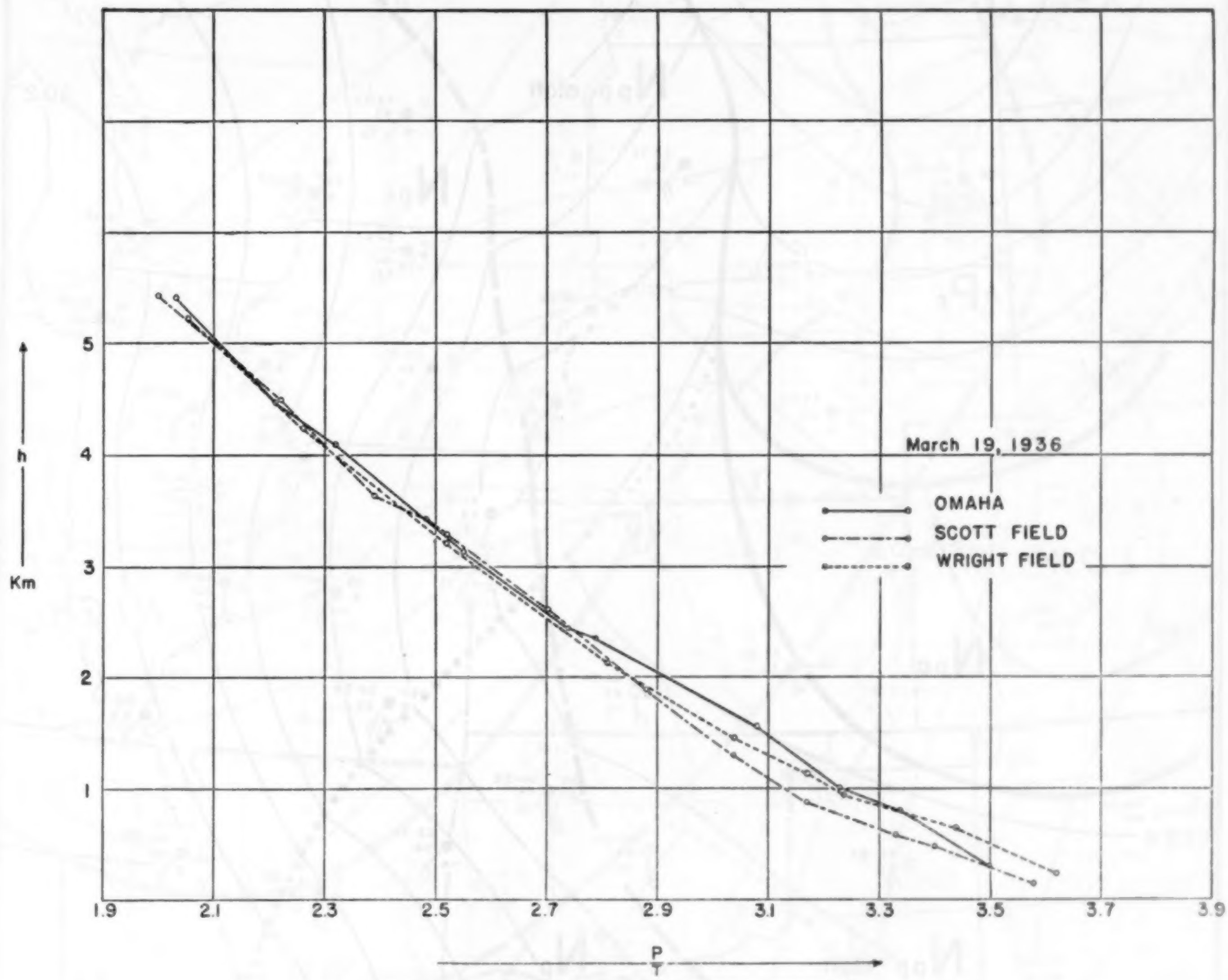


FIGURE 8.—Density-altitude curves; P/T in mb/°A, altitude in km.

The following illustration will serve to indicate the relative importance of changes in temperatures and pressures, and the effect of these changes upon density:

Since density, ρ, varies directly with pressure, P, and inversely with temperature, T, then

$$\rho=K\frac{P}{T}.$$

Differentiating,

$$d\rho=K\left[\frac{dP}{T}-\frac{P}{T^2}dT\right].$$

If the following values are assigned, P=1,000 millibars, dP=+10, T=300° A., dT=+3°, the change in density,

The relation between density, pressure, temperature, and humidity, as derived from the equation of state for moist air, is

$$\rho=\frac{P}{R_d\ (1+0.604q)\ T},$$

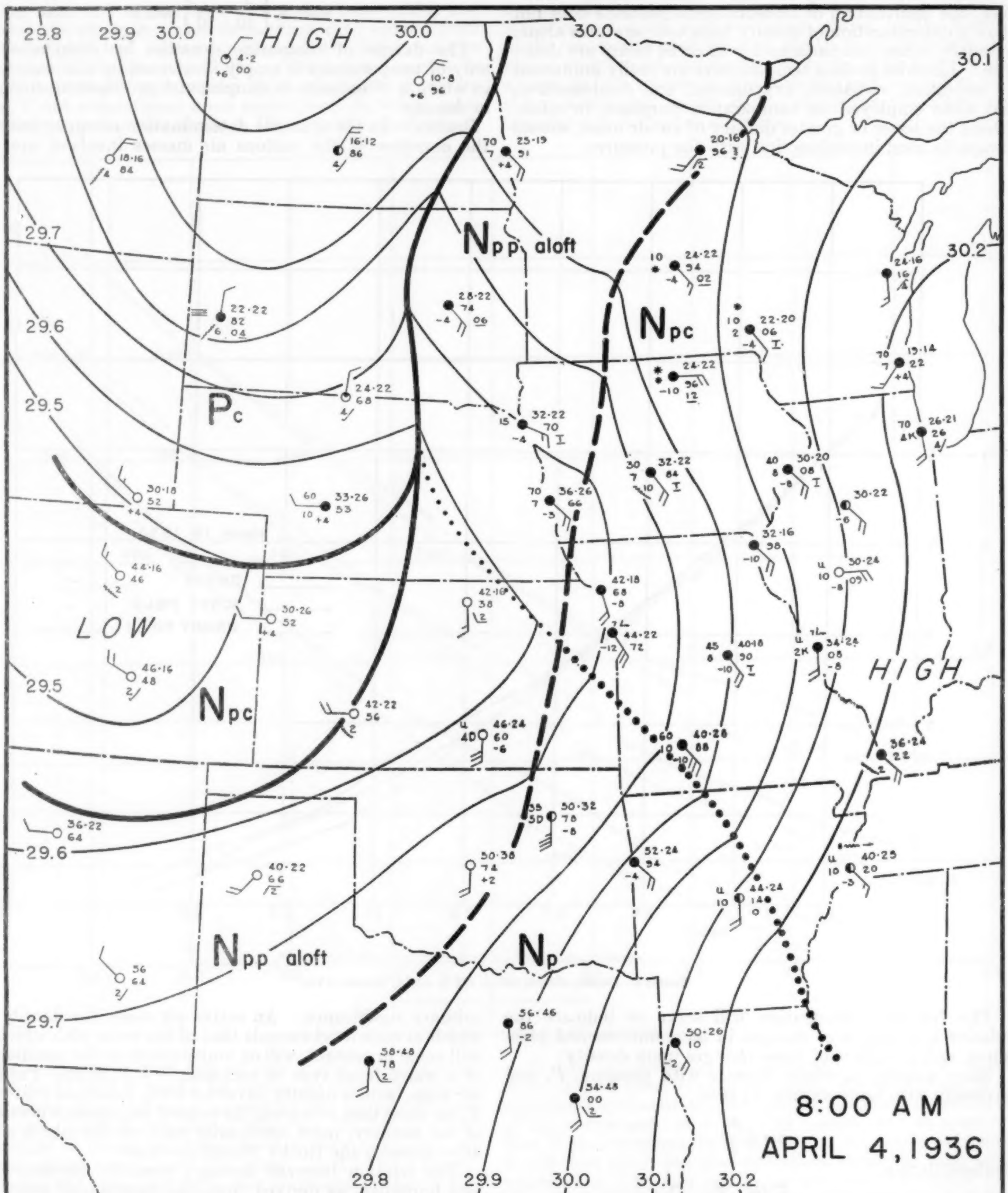

29.8
29.9
30.0
HIGH
30.0
30.0
30.1
29.7
Npp aloft
30.2
29.6
Npc
29.5
Pc
LOW
HIGH
29.5
Npc
29.6
Npp aloft
Np
29.7
8:00 AM
APRIL 4, 1936
29.8
29.9
30.0
30.1
30.2

FIGURE 9.

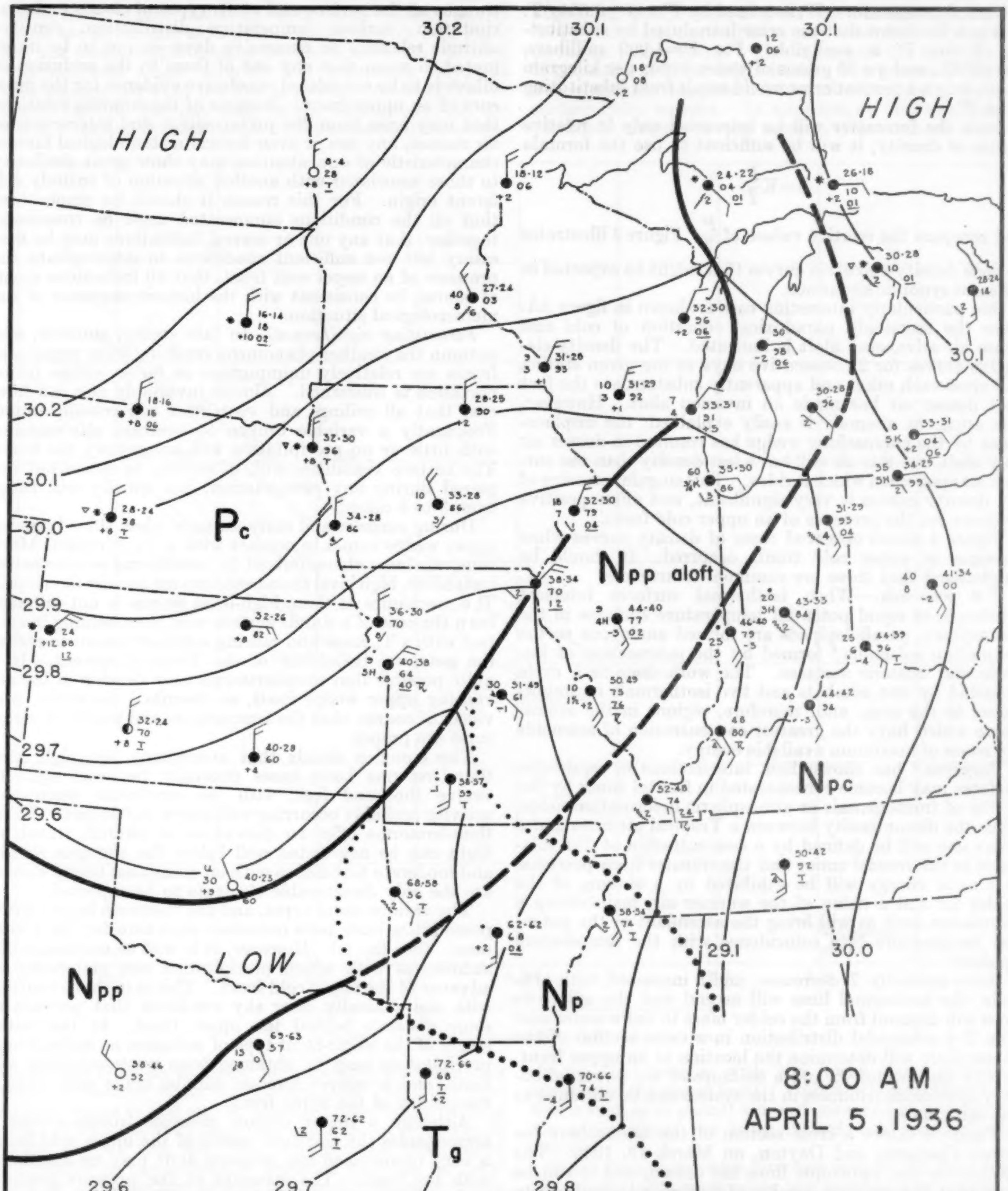

HIGH
HIGH
30.2
30.1
30.1
30.2
30.1
30.0
29.9
29.8
29.7
29.6
Pc
Npp aloft
Npc
LOW
Npp
Np
Tg
29.1
30.0
30.1
29.6
29.7
29.8
8:00 AM
APRIL 5, 1936

FIGURE 10.

where ρ=density of humid air, P=pressure, R_d=gas constant for dry air, q=specific humidity, and T=temperature.

Virtual temperature, T', is defined by $T'=(1+0.604q)T$.

It can be shown that the error introduced by substituting T for T' is negligible. For P=1,000 millibars, T=20° C., and q=20 grams of water vapor per kilogram of air, only a 1 percent error would result from substituting T for T'.

Since the forecaster will be interested only in relative values of density, it will be sufficient to use the formula

$$\rho=K\frac{P}{T},$$

and compare the relative values of $\frac{P}{T}$. Figure 3 illustrates various density-elevation curves that might be expected in different synoptic situations.

One particularly interesting case is shown in figure 3A. Here the seemingly paradoxical condition of cold and dense air advancing aloft is indicated. The density-elevation curves for 2 consecutive days at the given station will cross each other and apparently substantiate the fact that denser air has made an invasion aloft. However, this apparent anomaly is easily explained; the displacement by the encroaching wedge has resulted in denser air only aloft, but this air still has a less density than the surface air mass upon which it rides. This singular crossing of the density curves is very significant, and offers positive evidence for the presence of an upper cold front.

Figure 4 shows observed cases of density curves when passages of upper cold fronts occurred. It should be emphasized that these are common occurrences.

T–θ solenoids.—When isothermal surfaces intersect isentropic or equal potential temperature surfaces in the atmosphere, parallelepipeds are formed analogous to the circulation solenoids [8] formed by the intersection of isobaric and isosteric surfaces. The work done in a cycle bounded by two adiabats and two isothermals is proportional to the area; and, therefore, regions in the atmosphere which have the greatest concentration of solenoids are zones of maximum available energy.

Bergeron [9] has shown how intersections of equiscalar surfaces may become concentrated in frontal zones by the action of frontogenesis or atmospheric deformation fields. Thus the discontinuity between a Tropical air mass and a Polar one will be defined by a concentration of T–θ solenoids in the frontal zone; and the transfer from potential to kinetic energy will be exhibited by a sinking of the colder air and a rising of the warmer air, maintaining a circulation such as will bring the ascendant of the potential temperature into coincidence with the temperature gradient.

Since normally T decreases, and θ increases, with altitude, the isothermal lines will ascend and the adiabatic lines will descend from the colder mass to the warmer one. The T–θ solenoidal distribution in a cross section of the atmosphere will determine the location of an upper front, or any discontinuity; and a measure of the potential energy of mass distribution in the system can be obtained at the same time.

Figure 6 shows a cross section of the atmosphere between Cheyenne and Dayton, on March 19, 1936. The isothermic and isentropic lines are drawn, and it can be seen that the greatest density of solenoids is confined to the active frontal zones.

[8] Bjerknes, V.: Das dynamische Prinzip der Zirkulationsbewegungen in der Atmosphäre. *Meteorologische Zeitschrift*, p. 97 and 145, 1900; also p. 97, 1902.

[9] Bergeron, T.: Über die drei dimensional verknüpfende Wetteranalyse. *Norske Videnskaps-Akademi Geofysiske Publikasjoner*, vol. 5, no. 6, 1928.

The preceding enumeration of various synoptic aids for the determination of upper cold fronts—winds aloft and at the surface, pressure change characteristics, pressure troughs at the surface and aloft, types of clouds and precipitation, surface temperature distribution, density-altitude relations on successive days—is not to be interpreted to mean that any one of these to the exclusion of others is to be considered conclusive evidence for the presence of an upper front. Because of the complex relations that may arise from the juxtaposition and interaction of air masses, any one or even several meteorological factors characteristic of one situation may show great similarity to those associated with another situation of entirely different origin. For this reason it should be emphasized that all the conditions enumerated must be considered together, that any one or several indications may be necessary but not sufficient conditions to demonstrate the presence of an upper cold front, that all inductions must, of course, be consistent with the historic sequence of the meteorological situation.

Forecasting significance.—In late spring, summer, and autumn the weather phenomena resulting from upper cold fronts are relatively unimportant as far as airline transportation is concerned. Almost invariably one can forecast that all ceilings and visibilities will remain ample. Frequently a variable broken to overcast alto-cumulus with little or no precipitation will accompany the front. The surface visibilities will, of course, be somewhat impaired during any precipitation, but usually will range from 3 to 8 miles.

During summer and early autumn when the advancing upper wedge comes in contact with a T_M (Tropical Maritime) air mass characterized by conditional or convective instability, high level thunderstorms are usually developed. The mechanics of these high-level storms is not different from the case of a simple surface cold front coming in contact with a T_M mass and causing sufficient ascent to realize the potential instability of the Tropical current. It is quite possible that thunderstorms may develop in the advancing upper wedge itself, as described elsewhere, provided, of course, that the temperature and humidity structures are proper.

The cumulus clouds that accompany the high level thunderstorms have bases generally between eight to twelve thousand feet, with the maximum convective activity probably occurring well above 18,000 feet. These thunderstorms offer no difficulties to aircraft travel, as flight can be negotiated well below the cumulus clouds, and moderate turbulence with an occasional heavy shower are the only disagreeable elements to be expected.

The various cloud types, and the "between layer" flying possibilities have been described elsewhere for the winter case. (See fig. 1.) However, it is well to emphasize the suddenness with which precipitation can materialize in advance of the upper cold front. This is in sharp contrast with the generally clear sky condition that prevails at some distance behind the upper front. In the initial stages of the warm-front type of occlusion no indication of precipitation may be obtained from westward-lying stations, and a correct forecast can be made only from a recognition of the upper front.

Although a minor surface pressure trough generally accompanies the eastward march of the upper cold front, a very pronounced low pressure aloft may be associated with the front. The intensity of the pressure gradient aloft will in turn bring about a significant increase in the velocities of the winds aloft, and winds of 60 to 70 miles per hour between 9,000 and 15,000 feet may be found.

The weather resulting from an upper cold-front situation in winter occasionally presents a serious icing hazard

to aircraft. This condition can best be illustrated by contrasting it with the icing hazards during a surface warm front situation. In the winter case of a simple warm front, where relatively warm moist southwesterly winds are advancing aloft over a wedge of very cold Polar air, the precipitation usually begins as snowfall. During this incipient stage, aircraft will experience no great difficulties other than the loss of power occasioned by the use of heat to prevent icing in the carburetor. As the warm front action continues, with the consequent modification of the Polar air to higher temperatures, a serious icing stage is reached when the precipitation from the alto-stratus begins as rain and on descent proceeds as a freezing rain. This hazardous stage may continue for from 8 to 12 hours, and by then the Polar wedge either has receded sufficiently or has become so modified that the temperature of precipitation is well above the freezing point. Moreover, in this warm front condition it is quite likely that in spite of the fact that the precipitation is freezing in the Polar wedge, a sufficient temperature inversion prevails aloft in the Tropical air for a rapid ascent through the Polar current to permit only a very slight accumulation of ice.

On the other hand the icing hazard that accompanies an upper cold front may cause considerable doubt as to the safety of navigation through the frontal zones. The advancing wedge aloft is generally warmer than the surface Polar mass, but will have only a small modifying effect upon the wedge below. This is because the air mass aloft is generally of Polar origin itself. It is also unlikely that any significant temperature inversion is present above the surface Polar current. In addition, an "on top flight" is excluded because of the extreme thickness of the alto-stratus that merges with the lower cloud systems in advance of the upper front. Once the temperature condition is such as to permit a mixed snow and rain to fall from the alto-stratus, the icing hazard can become indeed serious.

When the upper wedge interacts with T_M air, icing conditions seem to be confined to the cloud system within the Tropical current. This conclusion is based upon evidence furnished by a number of pilots of American Airlines, Inc.

Three meteorological situations have been selected and are briefly described below. These synoptic examples have individual complexities and some analytical difficul-

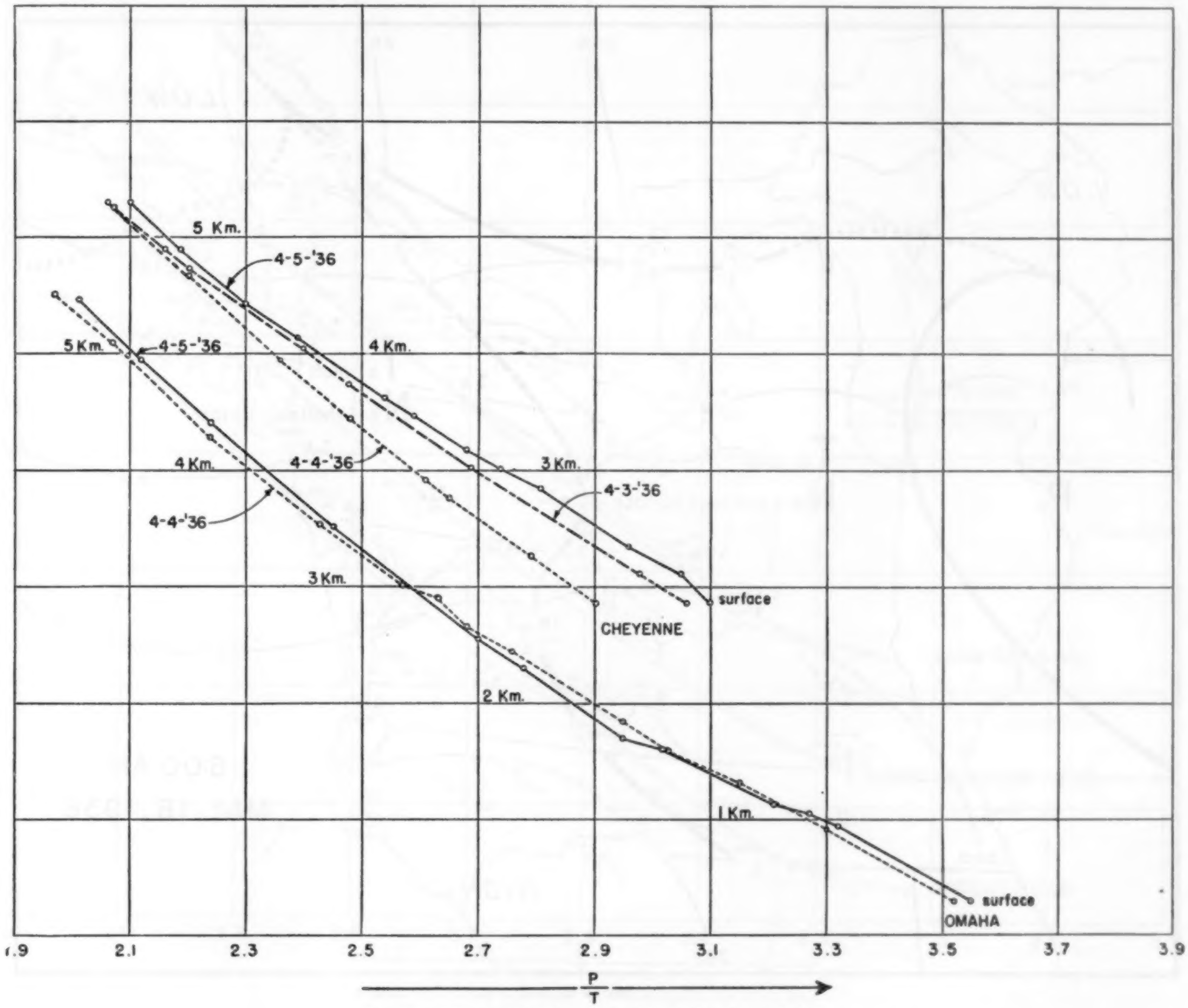


FIGURE 11.—Density-altitude curves; P/T in mb/°A, altitude in km.

ties, but nevertheless are quite representative. In figures 5, 9, 10, and 12, in which the individual situations are represented, the solid line represents the cold front, the dotted line the warm front, the dashed line the cold front aloft, and the dot-dashed line the occluded front. The wind arrows fly with the wind and each bar indicates two units of wind force on the Beaufort scale. The meteorological observations are generally grouped so that the temperature and the dew-point are to the upper right of the station; pressure directly under the temperature; precipitation, if any, under the pressure; ceilings in hundreds of feet to the upper left; visibility directly under the ceiling; and pressure tendency below the station.

March 19, 1936.—The most frequent type of upper cold front appears as a P_p front aloft in the Middle West when the central and eastern portions of the country are occupied by fresh P_c air. An interesting situation of this type, illustrating both an upper cold front and a cold front type of occlusion, occurred on March 19, 1936. The surface conditions are represented in figure 5, and an east-west cross section through the atmosphere in figure 6.

An upper cold front, outlining the boundary of a transitional type of P_p air, is present between Scott Field and Wright Field, and is advancing over a shallow wedge of P_c air. A fresher surge of P_p air is indicated by the cold front between Omaha and Scott Field. This front is proceeding eastward and is displacing the shallow layer of return P_c air as a cold front type of occlusion, because the active P_p air mass is of the greater density.

The density relations for this synoptic situation completely verify the indicated conditions. Figure 7 shows the density curves for Omaha, Scott Field, and Wright Field. The air mass at Omaha on the 19th has a much greater density, level for level, than the air column that was present there on the 18th. This necessarily indicates a surface invasion by a Polar air mass, and is represented by the outbreak of fresh P_p air. The density curves for Scott Field on the 18th and 19th illustrate the singular crossing of the curves which is characteristic of the passage of an upper cold front. The upper cold front passed Wright Field between the 19th and 20th; and these curves, similarly, show the peculiar crossing.

The density relations for Omaha, Scott Field, and Wright Field on the 19th are illustrated in figure 8. It can be seen that in the lower levels the Omaha curve shows a denser mass of air than the curve for Wright Field;

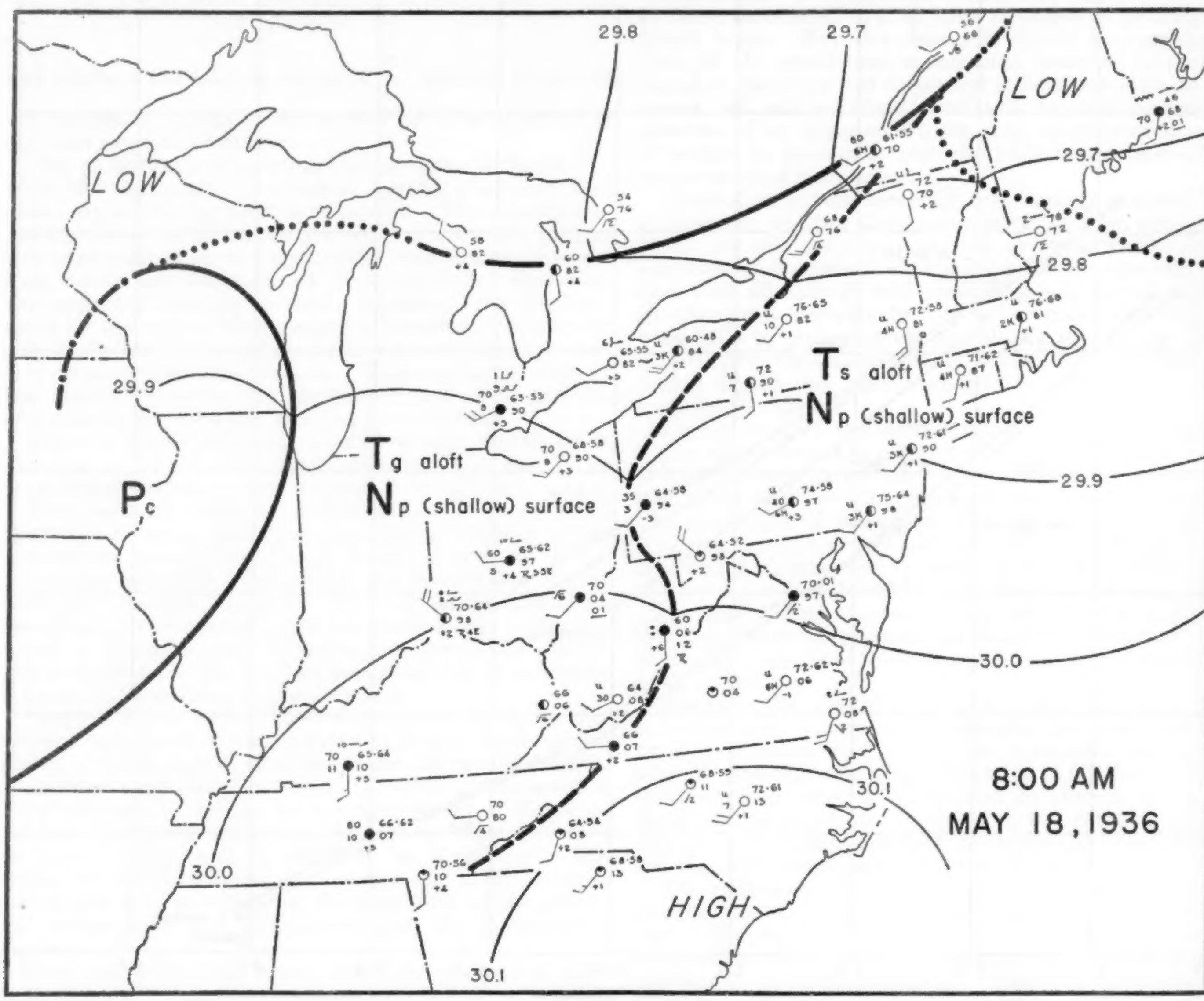


FIGURE 12.

and one of them must pass through the St. Louis area as a surface invasion. However, the air at Omaha below 800 meters is less dense than at the corresponding levels of the Wright Field curve, and thus indicates a possibility for the active P_p mass to occlude in the warm front manner by the time the air mass has invaded the Dayton area; but this possibility has to be substantiated by data at some later stage, for it is more than likely that at the time the P_p air is ready to invade the Dayton area, the dense layer of P_c air may have become sufficiently modified to be actually less dense than the advancing P_p air, and thus preclude the possibility of a warm front type of occlusion. The lower levels at Scott Field have a less density than the corresponding levels at Wright Field. This immediately eliminates the possibility of any surface cold front advancing into the Dayton area from the St. Louis area; and necessarily implies that as long as the indicated density relations prevail at these two stations, all air mass invasions must occur aloft.

No significant weather phenomena resulted from the upper cold front on the 19th; but on the 20th, a good deal of precipitation occurred, although the situation was then complicated by the advance of the cold front type of occlusion.

April 4 and 5, 1936.—Figures 9 and 10 show the 8 a. m. synoptic situations for April 4 and 5, 1936. On the 4th an upper cold front, marking the advance of N_{pp} (Modified Polar Pacific) air aloft over a dense wedge of P_c air, is oriented in a north-northeast to south-southwest direction through the Middle West. The front is particularly well-defined by the pronouned pressure change discontinuity that extends along the length of the front. To the east of the upper front, drops of 8 to 12 hundredths in 3 hours prevail; but immediately to the west of the front, drops of only 2 to 6 hundredths are generally found. A cold front marking a surface outbreak of fresh P_c air is present through the Dakotas and Nebraska, and it is interesting to note that no precipitation is taking place along the wind shift. However, in advance of the upper cold front, snow has developed throughout Wisconsin and Iowa and a rapid lowering of the ceilings has taken place.

On the 5th the upper front had advanced eastward, then extending through Michigan, Indiana, Illinois, Missouri, and Arkansas. The P_c cold front had actively

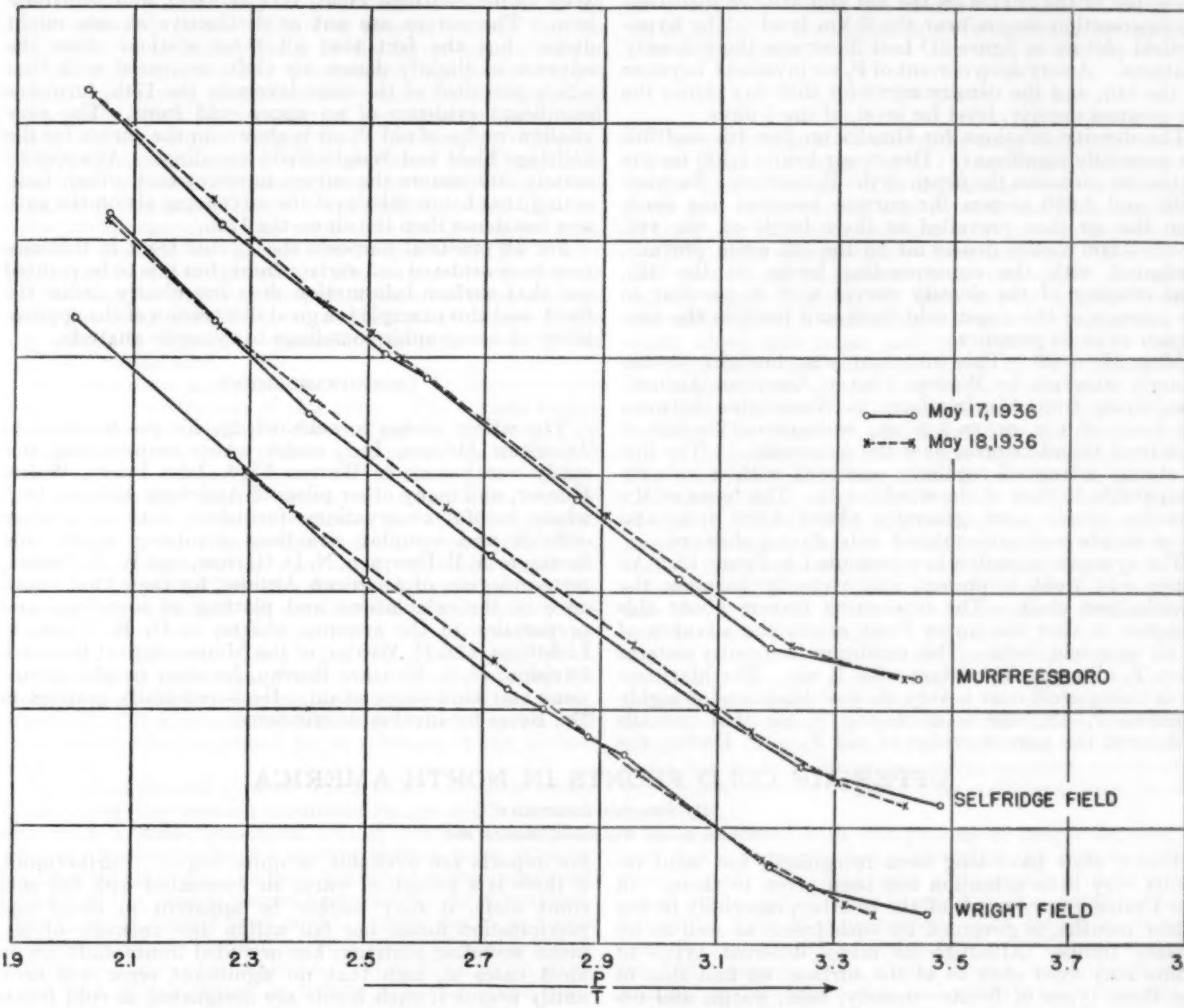


FIGURE 13.—Density-altitude curves; P/T in mb/°A, altitude in km.

advanced southeastward, and numerous snow squalls occurred within the air mass.

The density relations for Cheyenne and Omaha are illustrated in figure 11. The soundings at Scott Field, which would have been particularly interesting for this situation, were unfortunately not made, because of adverse flying conditions. However, the density curves for Cheyenne indicate less dense air on the 4th than had occupied the station on the 3rd. Some indication of the advance of the P_c air aloft is given by the fact that the slopes of the curves on the 3rd and 4th are such that the intersection occurs near the 5 km level. The hypothetical picture in figure 3D best illustrates these density relations. A very deep current of P_c air invaded Cheyenne on the 5th, and the density curve for that day shows the the greatest density, level for level, of the 3 days.

The density relations for Omaha on the 4th and 5th are especially significant. Denser air below 1,100 meters on the 5th indicates the depth of the P_c current. Between 1,100 and 3,000 meters the current becomes less dense than the air that prevailed at these levels on the 4th. Above 3,000 meters denser air on the 5th again prevails, compared with the corresponding levels on the 4th. This crossing of the density curves aloft is peculiar to the passage of the upper cold front and justifies the conclusion as to its presence.

May 18, 1936.—This situation was brought to the writer's attention by Warren Vine of American Airlines, who, flying from Murfreesboro to Washington between the hours of 1 p. m. to 5 p. m., encountered "a line of high level thunderstorms over the mountains." The line of storms advanced regularly eastward with a velocity comparable to that of the winds aloft. The bases of the cumulus clouds were generally above 8,000 feet, and lower clouds were encountered only during showers.

The synoptic situation is represented in figure 12. An upper cold front is present and virtually parallels the Appalachian chain. The interesting feature about this situation is that the upper front marks the advance of T_G air as a cold front. This condition frequently obtains when T_G air comes in contact with T_s air. The Maritime air is riding aloft over a very shallow thickness of highly modified P_c air, and is displacing T_s air that prevails aloft over the narrow wedge of old P_c air. During the day the air masses to the east of the upper cold front became considerably heated, and as the T_G air invaded the region a very unstable condition was produced. High-level thunderstorms developed during the afternoon with the advance of the upper front, and continued to accompany the front as it passed off the coastal regions during the evening. The storms developed in the advancing T_G air, as the T_s air was much too dry to produce any thunderstorm activity.

Figure 13 shows the density relations on May 17 and May 18 for Selfridge Field, Wright Field, and Murfreesboro. The curves are not as distinctive as one might desire; but the fact that all three stations show the advance of slightly denser air aloft, compared with that which prevailed at the same levels on the 17th, furnishes significant evidence of an upper cold front. The very shallow wedge of old P_c air is shown on the curves for the Selfridge Field and Wright Field soundings. At approximately 500 meters the curves intersect each other, indicating that below this level the advancing air on the 18th was less dense than the air on the 17th.

For all practical purposes the T_G cold front in this case may be considered as a surface front; but it is to be pointed out that surface information does not clearly define the front, and this example is a good illustration of the applicability of aerographic soundings to synoptic analysis.

ACKNOWLEDGMENTS

The writer wishes to acknowledge his indebtedness to American Airlines, Inc., under whose employment this study was begun; to Warren Vine, John Pricer, Walter Hunter, and many other pilots of American Airlines, Inc., whose helpful observations furnished data to analyze difficult and complex situations involving upper cold fronts; to A. B. Bowman, N. D. Garrow, and W. E. Pereira, meteorologists of American Airlines, for their kind assistance in the calculations and plotting of soundings and preparation of the synoptic charts; to H. R. Byers, S. Lichtblau, and H. Wexler, of the Meteorological Research Division, U. S. Weather Bureau, for their helpful discussions and kind cooperation. He is especially grateful to Dr. Byers for invaluable criticisms.

UPPER-AIR COLD FRONTS IN NORTH AMERICA

By STEPHEN LICHTBLAU

[Weather Bureau, Washington, December 1936]

Fronts aloft have long been recognized, but until recently very little attention has been given to them. In the United States much of the weather, especially in the colder months, is governed by such fronts as well as by surface fronts. Although as many different types of fronts may exist aloft as at the surface, we find that of the three types of fronts—namely, cold, warm, and occluded—only the cold front has much significance aloft, and it is by far the easiest to locate. Warm fronts aloft may occasionally be located when they are accompanied by well defined synoptic phenomena; but usually the meteorological elements, with the exception of precipitation, indicate gradual changes rather than the abrupt changes found with the passage of cold fronts aloft.

Occluded fronts are identified as such from their past history, if possible, or with the aid of airplane soundings; the soundings should show a trough of warm air in advance of the cold front aloft. However, many of the fronts designated as cold fronts aloft may in reality be occluded fronts aloft, since in many cases the history of such fronts moving eastward across the Pacific, where few reports are available, is quite vague. Furthermore, if there is a trough of warm air associated with the cold front aloft, it may neither be apparent in cloud and precipitation forms nor fall within the network of airplane sounding stations; but occluded fronts aloft are in most cases so high that no significant error will ordinarily accrue if such fronts are designated as cold fronts aloft. The following discussion is therefore limited to upper air cold fronts.

FORMATION

Cold fronts aloft may in most cases be traced back to surface occlusions of the warm front type. One exception occurs with frontogenesis aloft above a shallow polar current, usually of continental origin. The considerations for frontogenesis are as applicable aloft as they are on the surface.[1] Another exception of a more complicated nature occurs as a development in the advance portion of a deep polar current, in the form of a steepening of the slope of the polar wedge at some distance behind the

[1] Petterssen, Sverre: Contribution to the theory of Frontogenesis, Geofysiske Publikasjoner, vol. XI, no. 6.

surface front. This implies either a decrease in wind velocity or a change in wind direction above the elevation where the slope steepens, in such a manner as to cause the lower portion of the air mass to advance more rapidly than the upper portion. The precipitation may at times be more pronounced with an upper air front formed in this manner than with the associated surface front. The reverse of the above process will explain the formation of most warm fronts aloft.

These exceptions, while often important, occur much less frequently than the cold fronts aloft found with warm type occluded fronts. The two general regions for the formation of occluded fronts of the latter nature, as far as United States weather is concerned, are in the Pacific Ocean at varying distances from our coast (depending principally upon the location of the Aleutian LOW) and along the mountain ranges from California to Alaska. When the occlusion of a warm sector of modified Polar Maritime air occurs at some distance from the coast we find, with the warm front type of occlusion, that the surface air is warmer to the west than to the east, which permits the air to the west to ascend over the colder wedge as it moves eastward. Aloft, however, in the air to the west we find low temperatures, sometimes exceedingly low with steep lapse rates that often approach the dry adiabatic lapse-rate characteristic of fresh outbreaks of Polar Pacific air.[2]

The diagrams in figures 1*a*, 1*b*, and 1*c* illustrate the formation of occlusions of this type. The surface occlusion which was originally the surface warm front may advance slowly or even remain stationary, while the cold front advances rapidly over the shallow polar wedge. The separation of these fronts may increase quite rapidly to a thousand miles or more. Also, the surface occlusion may have become insignificant from a synoptic viewpoint, remaining near the west coast, while the upper air front has traversed half the distance or more across the country, accompanied by considerable precipitation, the amounts of course depending upon the air masses encountered. In some cases, when the Pacific analysis is incomplete or inaccurate because of insufficient reports from ships at sea, it is impossible to find the surface front, especially if it is associated with a prominent upper cold front which has progressed far in advance of the surface occlusion.

The other general type of warm front occlusion which forms along the western mountain ranges needs no LOW nor even a well-pronounced trough for its formation: East of the mountains is a shallow surface layer of polar continental air which has been unable to spread westward because of the natural barrier presented by the mountains. This P_c air is usually very cold.[3] Above the P_c is found P_p which has gone through varying stages of modification, usually by means of subsidence. Fresh P_p air, with steep lapse rate, which comes in behind a surface cold front along the west coast, is colder than the modified P_p air and displaces it while moving eastward and ascending the mountains. After reaching the P_c air on the other side of the mountains it continues its movement as a cold front aloft, above and without displacing this P_c air, rather than as a surface front. The movement of such an upper air front will often be considerably accelerated after the retarding influence of the mountains has been overcome or left behind. Again, as in the other general case, the cold front aloft may advance rapidly across the country while the surface occlusion or surface warm front advances slowly or even remains stationary. The diagrams in figures 2*a* and 2*b* illustrate the formation of this type of occlusion.

Other occlusions of the warm front type may form anywhere over the continent.[4] With the type of warm front occlusion described by Wexler, however, the cold front often remains in close proximity to the surface occlusion as it advances across the country and seldom progresses so far ahead of the occlusion as in the other two types of cold fronts aloft.

LIFE HISTORY

The cold front aloft moves in most instances above a P_c air mass of average depth approximately 2,000 meters in the United States. This depth may vary considerably, from zero at the surface cold front in the advance portion of the P_c air mass to as much as 4,000 meters in the central portion under extraordinary circumstances.[5] Usually the cold front aloft encounters little resistance, and moves rapidly across the country without ever coming down to the surface; but occasionally waves and cyclogenesis will occur along the front, and by disturbing the surface pressure field may cause the front to be propagated to the surface. As a rule cold fronts aloft, with any disturbances that form on them, remain aloft in the western portion of the country, and descend or are propagated to the surface only after they pass the Mississippi River. The cold front aloft may come to the surface simply by overtaking the surface cold front at the forward portion of the P_c current that it had originally surmounted; in most such cases, the two fronts will then advance as one surface front with the velocity of the cold front aloft, but sometimes after the cold front aloft overtakes the surface front it will continue to move as a surface front and increase its distance from the P_c front. Since a descent of air over the forward portion of a polar wedge necessarily implies subsidence, it is apparent that the process just described could not be responsible for so much precipitation as had occurred before the beginning of the descent; but, by accelerating the P_c front, it could bring about lower temperatures much sooner than the forecaster would expect if he considered only the surface front.

In comparison with this process of simple descent, we find that a propagation downward to the surface is more complicated. The cold front aloft usually will be propagated to the surface when it comes over a surface pressure trough or field of convergence. The trough or field of convergence without a front may already be a good region for frontogenesis, with winds having a southerly component on the eastern side and winds with a westerly or even northerly component on the western side. The winds associated with the cold front aloft are more accentuated on either side of the front and will show a well-marked trough in the isobaric field at the top of the surface layer of cold air. When the pressure trough associated with the upper front becomes superimposed upon the surface pressure trough we find that a surface cold front forms, with well-marked wind shifts and other

[2] Byers, H. R. The Air Masses of the North Pacific, Scripps Institute of Oceanography Technical Series, vol. III, pp. 311-354.

[3] Wexler, H. Cooling in the Lower Atmosphere and the Structure of Polar Continental Air, MONTHLY WEATHER REVIEW, vol. 64, no. 4.

[4] Wexler, H. Analysis of a Warm Front Type Occlusion, MONTHLY WEATHER REVIEW, vol. 63, no. 7.

[5] Wexler, Loc. cit.

characteristics of such fronts. If vertical mixing has taken place, the surface cold front will be continuous with the upper front and there will be but one front. If little or no mixing has taken place, the cold front aloft will continue to advance aloft and will outstrip the surface cold front that it generated in the field of convergence. This type of frontogenesis, in contrast with the type which does not require the aid of a cold front aloft, can be anticipated much more confidently, because the progress of the cold front aloft can be followed quite accurately for sometime before it enters the region where frontogenesis is likely. It is the opinion of the writer that in most instances surface frontogenesis over the North American continent occurs with the aid of upper air cold fronts in the manner described above.

Cyclogenesis, or the intensification of a LOW, will take place if the cold front aloft encounters a stagnant or slow-moving surface cyclone. The cyclone will intensify and move rapidly along the upper-air front, which then becomes a surface cold front south of the center. Here again a knowledge of the movement of the cold front aloft is important to the forecaster.

The movements of cold fronts aloft can be determined with fair accuracy because such fronts are affected by frictional influences to a less degree than are surface fronts. The 3-hour pressure tendencies and the 12-hour pressure change chart are more useful as qualitative rather than as quantitative indications of the movements of cold fronts aloft. Unfortunately kinematic computations, except in isolated cases, have little meaning, because the pressure field on the surface map is governed to a considerable extent by the lower air. It is equally unfortunate that a cold front aloft in close proximity to a surface front will complicate the pressure tendency field to such an extent that rigid kinematic computations made on the surface front will produce fallacious results. It has been found that the winds aloft, when they are available, within the air mass behind the cold front aloft will give the most reliable quantitative determination of the movement of the cold front aloft.

It has been found that cold fronts aloft are sometimes confused with fronts formed by frontogenesis, especially in regions where weather reporting stations are far apart. For example we often find in northwestern Canada two well-developed HIGHS separated by a trough, where on earlier maps there was but one HIGH. The previous history of these HIGHS may not show a surface front in the trough, although there now are good indications of a cold front of some nature. The pressure tendencies west of the trough will show well-marked rises, while east of the trough the pressures are falling. This region, even with a well-developed trough, may not have a temperature distribution in the low levels favorable for frontogenesis. If conditions are not favorable for frontogenesis, it is logical to conclude that if there is a front in the trough it must be a cold front aloft which could have been traced back to the Pacific on previous maps had sufficient data been available. Such a history could not be found for a front formed by frontogenesis in the Canadian Northwest. If, on the other hand, conditions are favorable for frontogenesis, we find that a surface front will be formed and will usually move slowly in this region, while a cold front aloft will continue its rapid movement.

RECOGNITION AND EFFECTS

A cold front aloft is at times easily detected and located on the surface map, while at other times its location becomes indefinite. If the processes of formation from occlusion have been observed, either over the Pacific Ocean or in the mountain regions, there is less difficulty in finding the cold front aloft, since it is expected. Difficulties arise when the formation is not observed. We then become aware of the front either from upper air data or from surface indications. The cold front aloft will have little influence on the surface temperatures as long as it remains aloft. It is not unusual to find the surface air moving in a direction opposite to that of the air aloft behind the cold front. The surface isobars along the cold front aloft will show a trough with no sharp discontinuities at the front.

Pressure tendencies afford the best clue for both the recognition and the determination of the progress of the cold front aloft. The forms of precipitation characteristic of P_p air when it is unstable will be observed falling through the shallow surface P_c air mass. In the advance portion

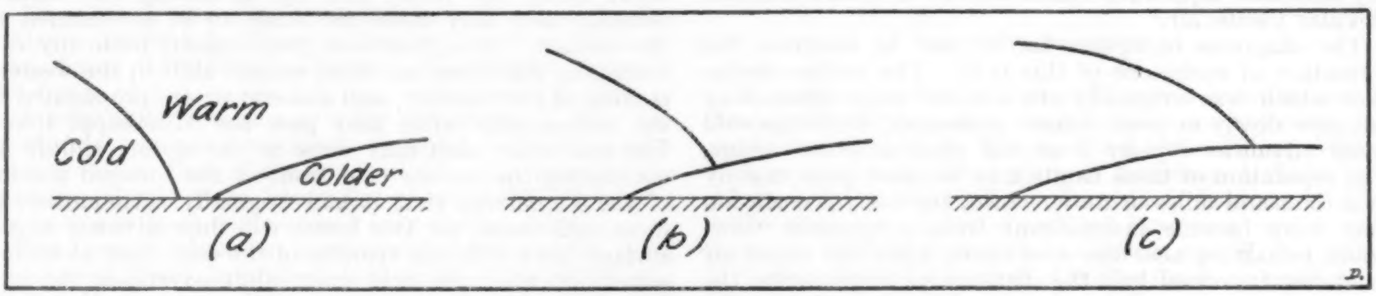


FIGURE 1.

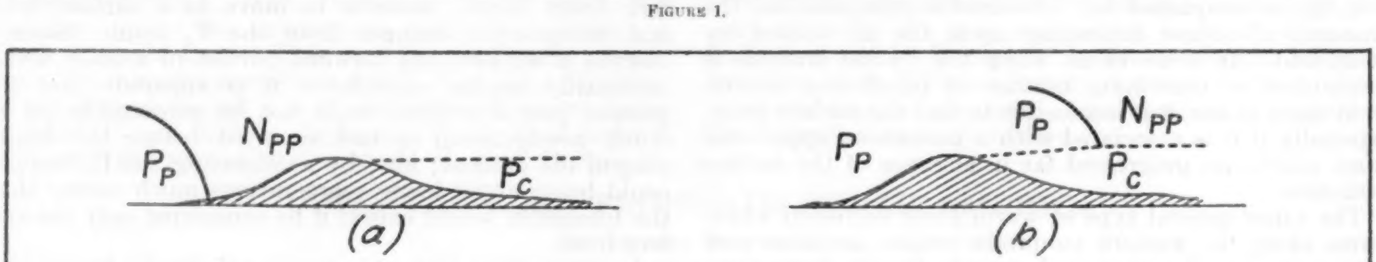


FIGURE 2.

of the front there may be considerable precipitation if the air mass in advance is moist and is forced upward. The front then resembles a surface cold front in many respects, but cannot be a surface front because it moves against the surface gradient and consequently against the surface winds. Airplane observations not only substantiate, but often reveal, the existence of the cold front aloft before its effects are observed on the surface map. There is always an increase in potential temperature and usually a well-marked temperature inversion at the surface or zone of separation between the surface air and the air above which has come in behind the cold front aloft. Also the cold air aloft contrasts sharply with the warmer air which it is displacing.

The foregoing discussion has been limited to the simple cases which occur during the colder months of the year, when cold fronts aloft are most frequent and most prominent. Such fronts do exist throughout the year, and may involve the juxtaposition of any group of air masses. The only condition necessary is that the lower air mass have at all elevations a greater density than the upper air mass.

The exceedingly cold air behind the front in Montana can be nothing but P_c which is part of the same air mass that is found east of the front in the Dakotas, Nebraska, Kansas, and Oklahoma.

Three airplane observations made on this day—one at Spokane at 4 a. m., one at Seattle at noon, and one at Cheyenne at 4 a. m.—conclusively demonstrate the existence and progress of the cold front aloft. The temperatures at all levels at Spokane and at Seattle dropped as much as 16° C. at 4,000 meters during the previous 24 hours, while the changes at Cheyenne, in advance of the front, were negligible in that period. At Spokane the very low temperature of −40° C. was observed at 5,300 meters. Seattle, where the observation was taken 8 hours later, had somewhat higher temperatures because at that time it must have been in the rear and warmer portion of the P_P air mass. In figure 7 the top of the surface P_c air mass is marked at Spokane by an isothermal layer throughout which the winds shift from NE. to NW. with increasing elevation; while at Seattle the P_c air is limited to the top of the isothermal layer at about 2,600 meters.

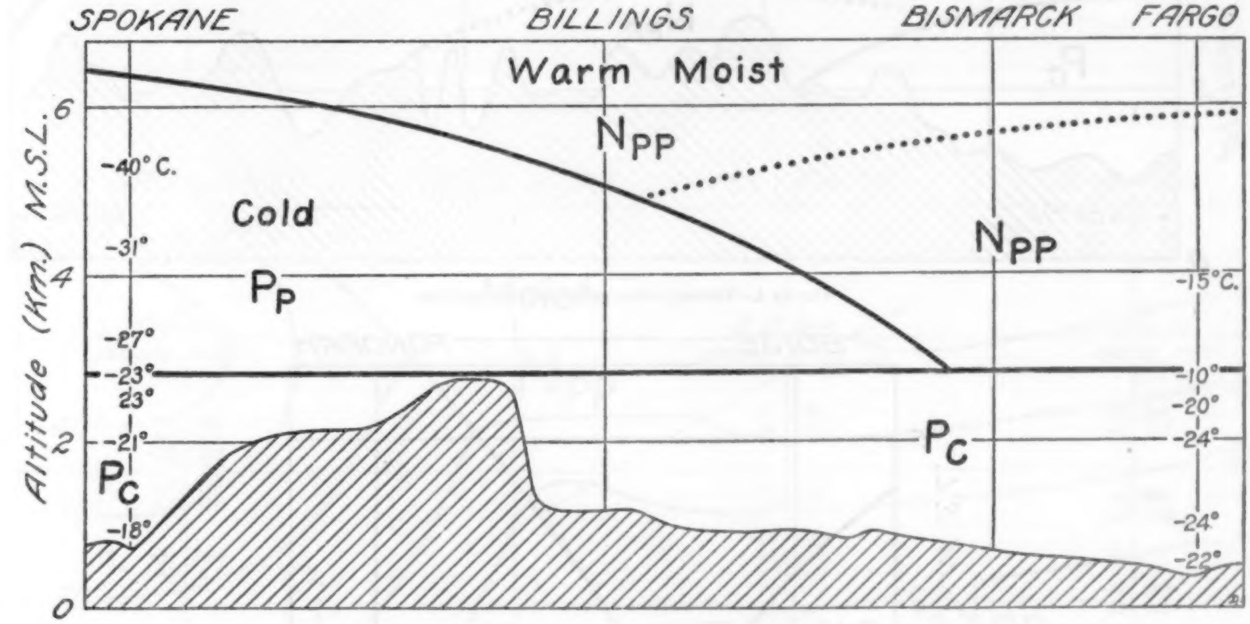


FIGURE 3.—Vertical section, Spokane-Fargo.

In the summer months it is not unusual to find warm moist Tropical Maritime air behind a cold front aloft. In such a case the surface air mass is a modified Polar air mass, while very warm "Superior" air is found over the Polar air in advance of the T_M front aloft. An interesting situation of this nature is discussed in the contribution by B. Holzman in this issue of the REVIEW, p. 400.

EXAMPLE

A well-developed cold front aloft appeared on the 8 a. m. map of February 13, 1936. Although this particular front was not well marked on previous maps, its movement could be observed after it formed from a warm front occlusion in the Gulf of Alaska. Even a cursory examination of the pressure tendencies on the 8 a. m. map of February 13 indicates a front of some nature, with Williston and Rapid City on one side and Bismarck and Valentine on the other side; and an inspection of previous maps shows that the front had been moving eastward against the prevailing surface pressure gradient. There is little difference in temperature on either side of this front.

Unfortunately, no airplane observation was made at Billings on this day.

South of this front there is another cold front aloft, which came in on the coast from the Pacific as a surface P_P cold front and became a front aloft after surmounting the shallow N_{PP} air mass ahead of the occluded front. The nature and progress of this cold front aloft had been detected and followed by indications from surface data, since no airplane observations were available at that time in that region. Again the principal evidence lies in the pressure tendencies at Grand Junction on one side of the front, and at Cheyenne, Denver, Pueblo, and Santa Fe on the other side. It is interesting to note the thunderstorms that occurred at Salt Lake City, Phoenix, and San Diego in conjunction with the front while it was still a surface front. These two cold fronts aloft are associated with two different air masses, with the one to the north much colder. It is merely a coincidence that the P_c surface front lies in the region where the two P_P air masses are in juxtaposition aloft.

The schematic vertical cross sections in figures 3, 4, 5, and 6 are presented in order to enable one to visualize a

three-dimensional picture of the upper air corresponding with the first surface map of the series. The warm moist N_{pp} air indicated on some of these sections must have existed at that time over only a small region and at comparatively high levels, since it was never actually found in any of the airplane observations although its progress could be observed with little difficulty on the surface map. The thunderstorms and the large amounts of precipitation in the Southwest show that such an air mass must have been present in advance of the P_p front. The cross section through Spokane, Cheyenne, and Omaha (fig. 7) shows this air to be apparent in conjunction with the altostratus clouds; and such an air mass is indicated at high levels in the vicinity of Billings.

We see then that we can account for most of the precipitation in the Southwest, except that occurring in California, with the aid of the moist N_{pp} air. This same air mass will account for some of the precipitation in the vicinity of the northern cold front aloft. Most of the precipitation, however, is occurring within the unstable P_p air mass itself, as evidenced by the snow flurries reported at some of the stations. The precipitation far in advance is not associated with either of the P_p fronts, nor with the warm moist N_{pp} air mass, but rather with a frontal system centered in Illinois.

On the next map of this series (2 p. m., Feb. 13), we have little trouble finding the fronts. Observe the rapid movements of both cold fronts aloft, and the progress of

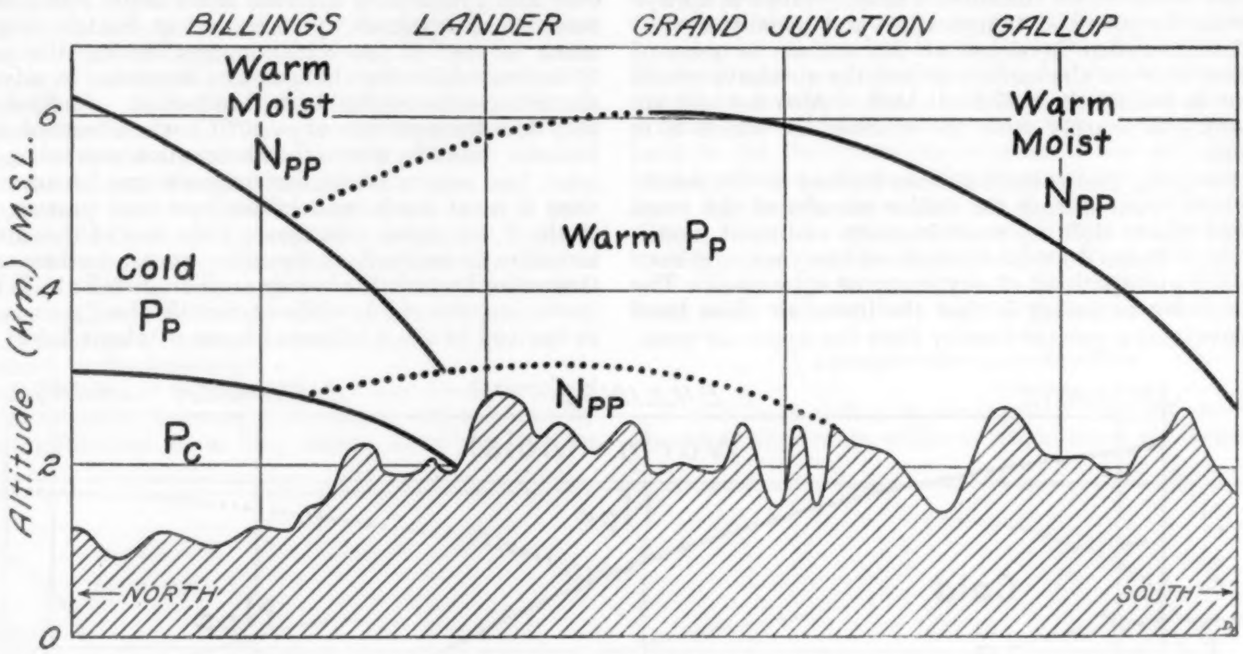


FIGURE 4.—Vertical section along the 108th meridian.

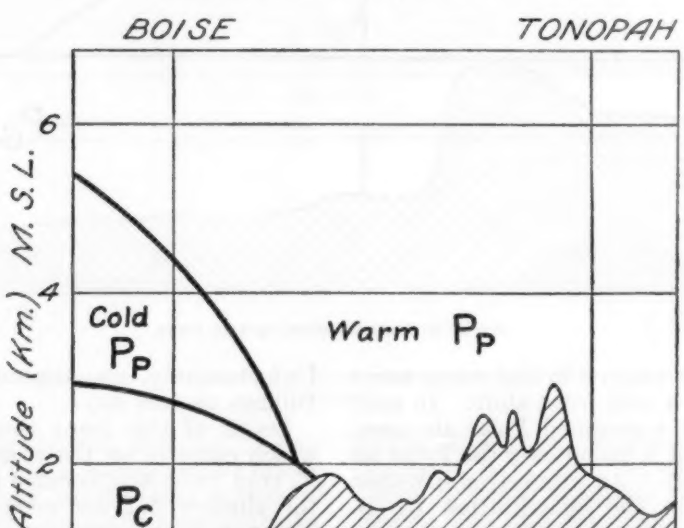


FIGURE 5.—Vertical section along the 117th meridian.

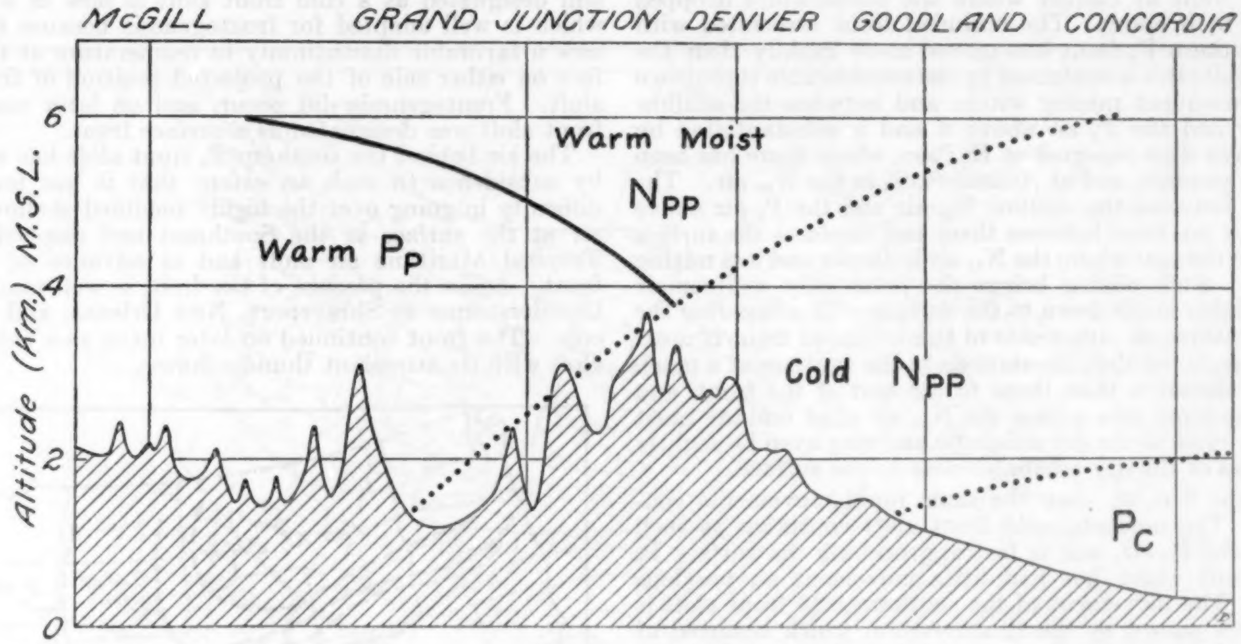


FIGURE 6.—Vertical section along 39th parallel of latitude.

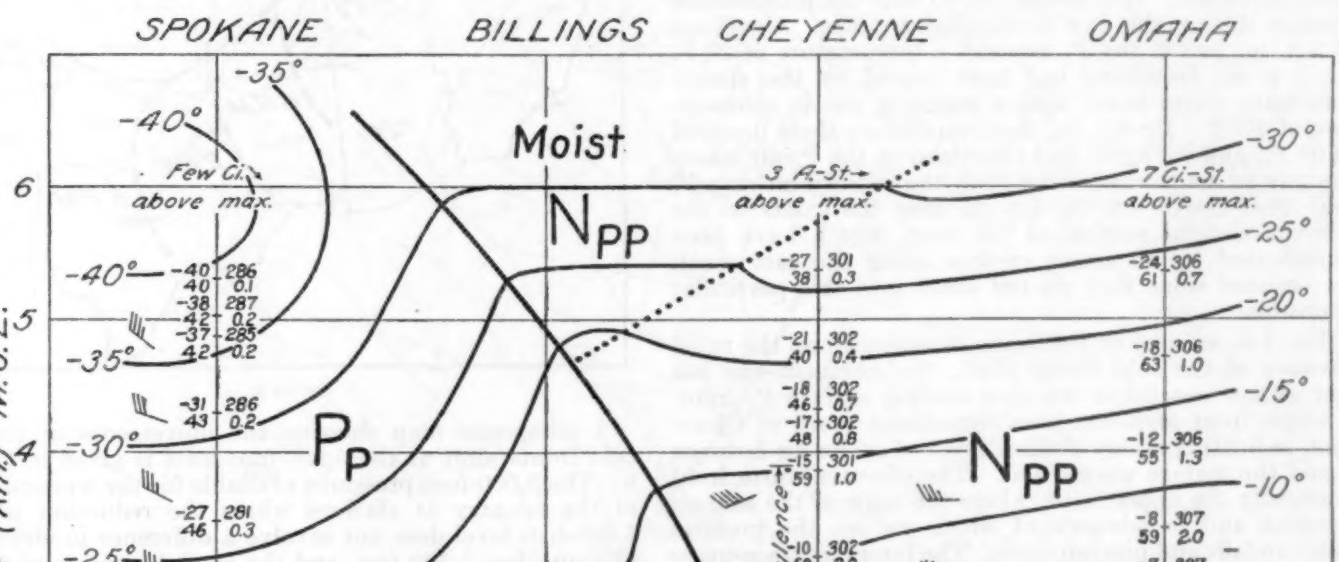


FIGURE 7.—Vertical section, Spokane-Omaha.

the P_c front at Lander where the temperature dropped 44° F. in 6 hours. The occluded front associated with the southern P_r front has moved more rapidly than the front aloft; this is explained by the considerable turbulence and consequent mixing within and between the shallow N_{pp} air and the P_r air above it and is substantiated by the heavy dust reported at El Paso, where there has been a front passage, and at Amarillo still in the N_{pp} air. The mixing between the shallow N_{pp} air and the P_r air above destroys the front between them and displaces the surface front to the east where the N_{pp} air is deeper and less mixing occurs. Such mixing brings the potentially warmer air from higher levels down to the surface. In comparing the temperatures on either side of this occluded front it must be remembered that the stations to the west are at a much higher elevation than those to the east of the front, and that the lapse rate within the N_{pp} air after midday must be very close to the dry adiabatic and may even be slightly in excess of the dry adiabatic close to the surface.

On the 8 p. m. map the same rapid movements continue. The northern cold front aloft continues as such above the P_c air, and is fast approaching the surface P_r cold front which has had little movement on previous maps. The movement of the southern cold front aloft is very well shown by the thunderstorm which occurred at Abilene between 5 and 6 p. m., and another one at Dallas which began at 7 p. m. and is continuing at the time of the observation. It is interesting to note the temperature changes during the day at Goodland, Kans. Goodland at 8 a. m. was in the P_c air with a temperature of 2° F. By 2 p. m. Goodland had been passed by the almost stationary warm front, with a resulting rise in temperature of 44° F. By 8 p. m. the temperature there dropped to 0° F., and we again find Goodland in the P_c air which has moved southward along with the rapidly moving P_c cold front aloft. On the 8 p. m. map the fronts on the extreme eastern portion of the map, which have been complicated by an active cyclone along the east coast, are omitted since they do not enter into this particular discussion.

The 2 a. m. map of February 14 again shows the rapid advance of the cold fronts aloft; the northern one has now almost overtaken the slow moving surface P_c front. A warm front aloft has been introduced south of Cleveland, indicating a very shallow layer of colder air between it and the surface warm front. The effective warm front is actually the upper front, where the slope of the cold air steepens and in advance of which we see the greatest pressure falls and precipitation. The temperature increase occurs behind the surface warm front.

On the 8 a. m. map of the same day we find that the northern cold front aloft has overtaken the surface P_c front and there is only one front, which is moving more rapidly than the P_c front had moved at any time during its history over the United States. The rapid movement continued for 12 hours, after which the structure of the front changed appreciably when it became influenced by other air masses in a region of considerable activity along the east coast. The northern part of the front which is still designated as a cold front aloft is now in a region which is well adapted for frontogenesis because there is now a favorable discontinuity in temperature at the surface on either side of the projected position of the front aloft. Frontogenesis did occur, and on later maps the front aloft was designated as a surface front.

The air behind the southern P_r front aloft has warmed by subsidence to such an extent that it has found no difficulty in going over the highly modified shallow polar air at the surface in the Southeast and displacing the Tropical Maritime air aloft and in advance of the P_r front. Again the passage of the front is well marked by thunderstorms at Shreveport, New Orleans, and Pensacola. The front continued on later maps as a cold front aloft with its attendant thunderstorms.

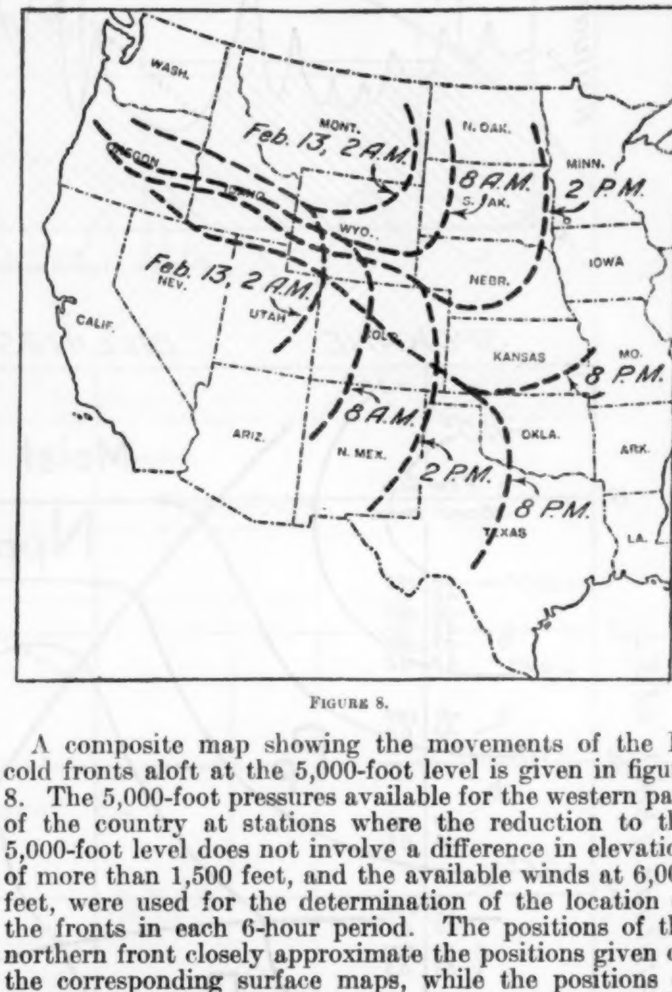
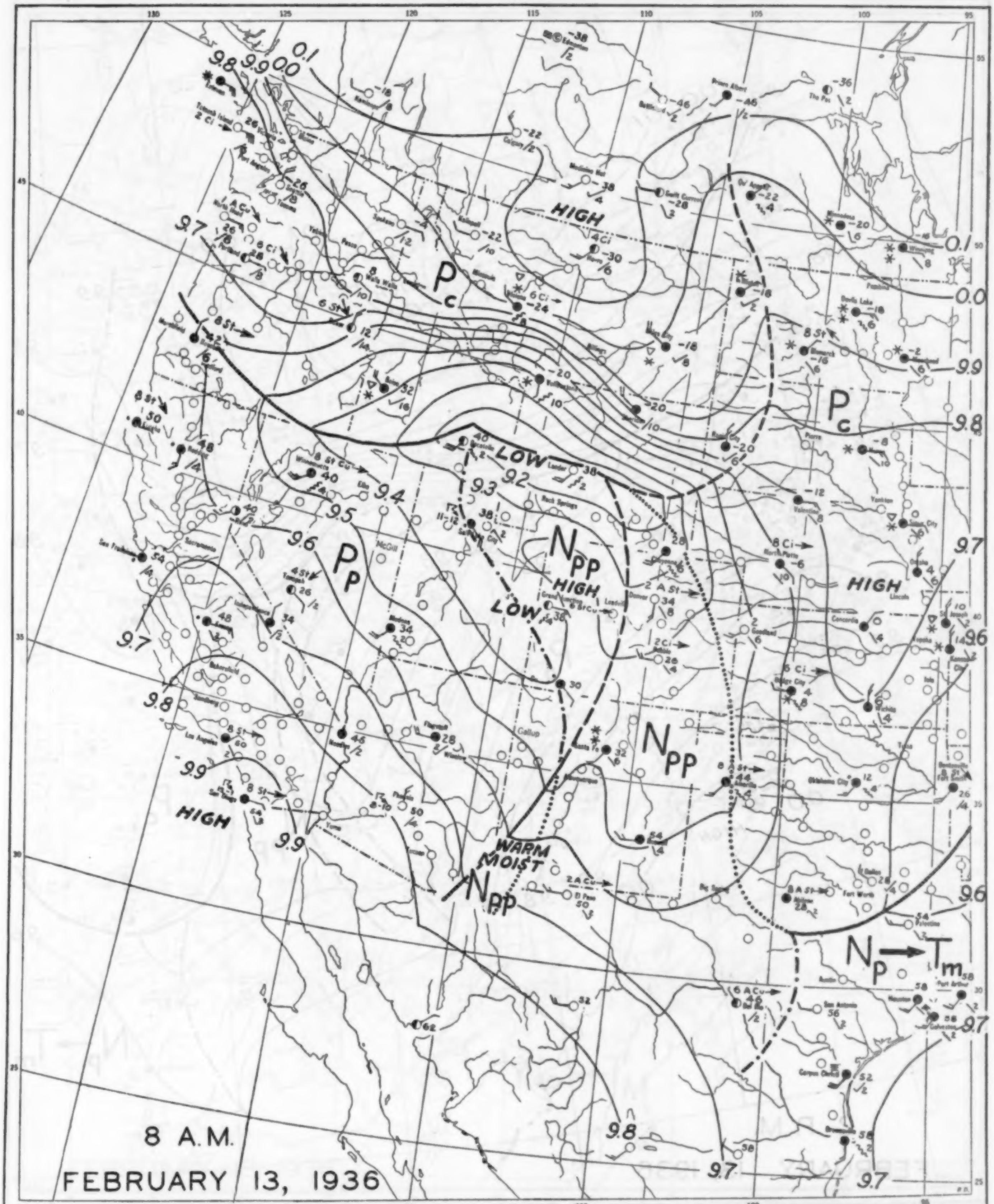
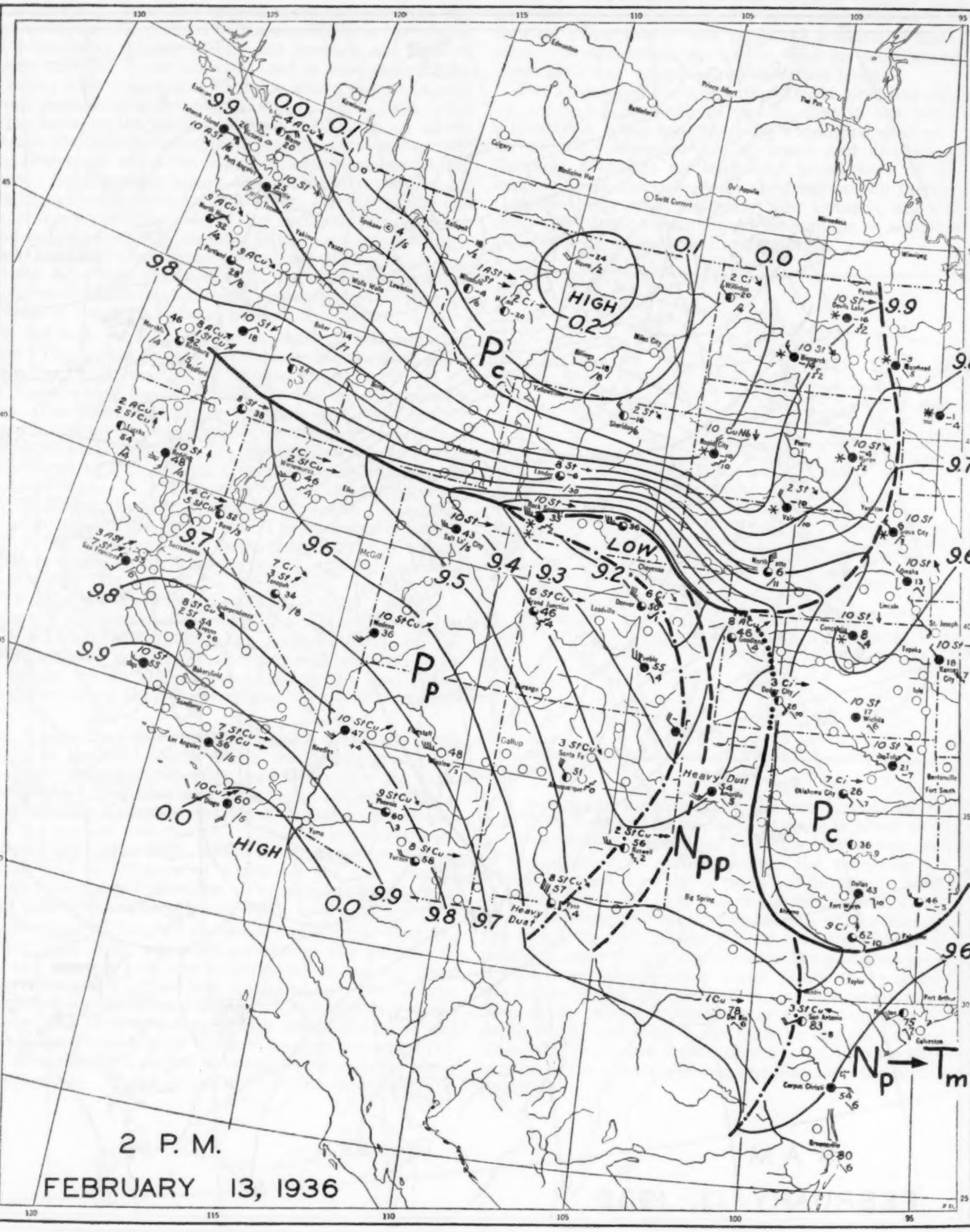


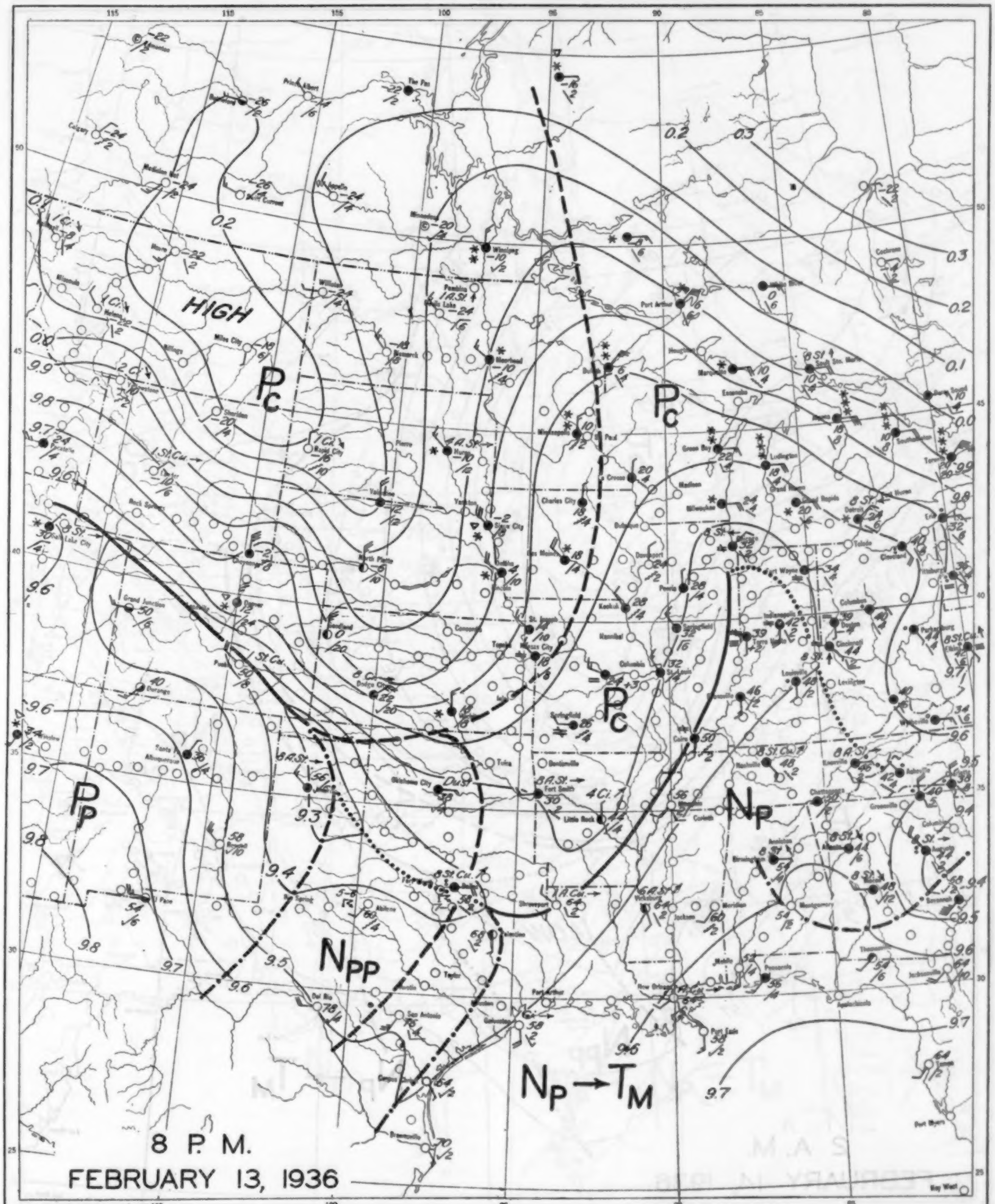
FIGURE 8.

A composite map showing the movements of the P_r cold fronts aloft at the 5,000-foot level is given in figure 8. The 5,000-foot pressures available for the western part of the country at stations where the reduction to the 5,000-foot level does not involve a difference in elevation of more than 1,500 feet, and the available winds at 6,000 feet, were used for the determination of the location of the fronts in each 6-hour period. The positions of the northern front closely approximate the positions given on the corresponding surface maps, while the positions of the southern front fall behind the surface positions in the later stages which indicates only a slow increase in the depth of the southern P_r air mass as one goes westward. These fronts are not shown after 8 p. m. because they fall outside of the network of stations that reported 5,000-foot pressures.



8 A.M.
FEBRUARY 13, 1936


2 P.M.
FEBRUARY 13, 1936
HIGH
LOW
HIGH
Heavy Dust
Heavy Dust


HIGH
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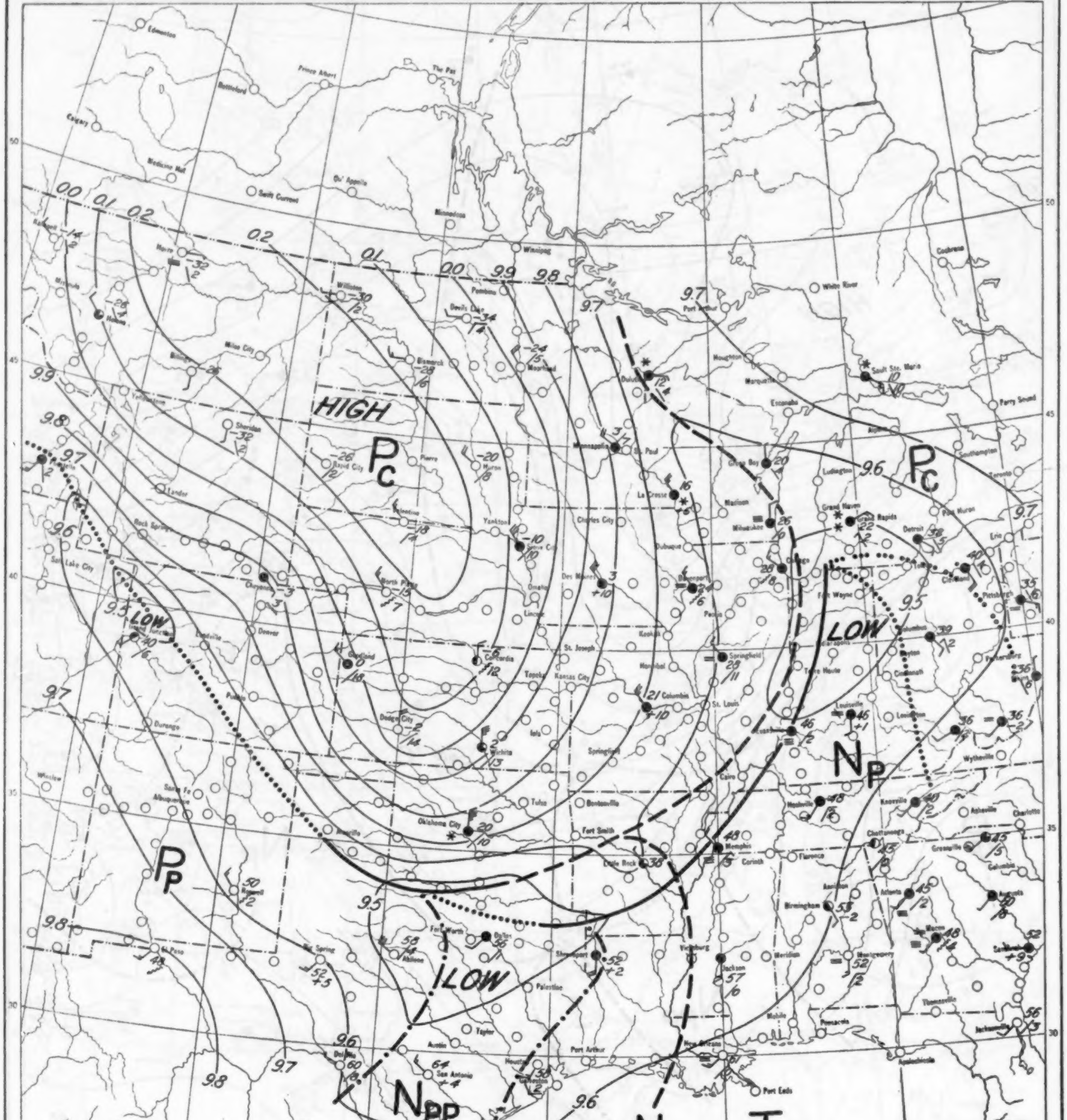
$N_P \rightarrow T_M$
8 P. M.
FEBRUARY 13, 1936


HIGH
P_C
P_C
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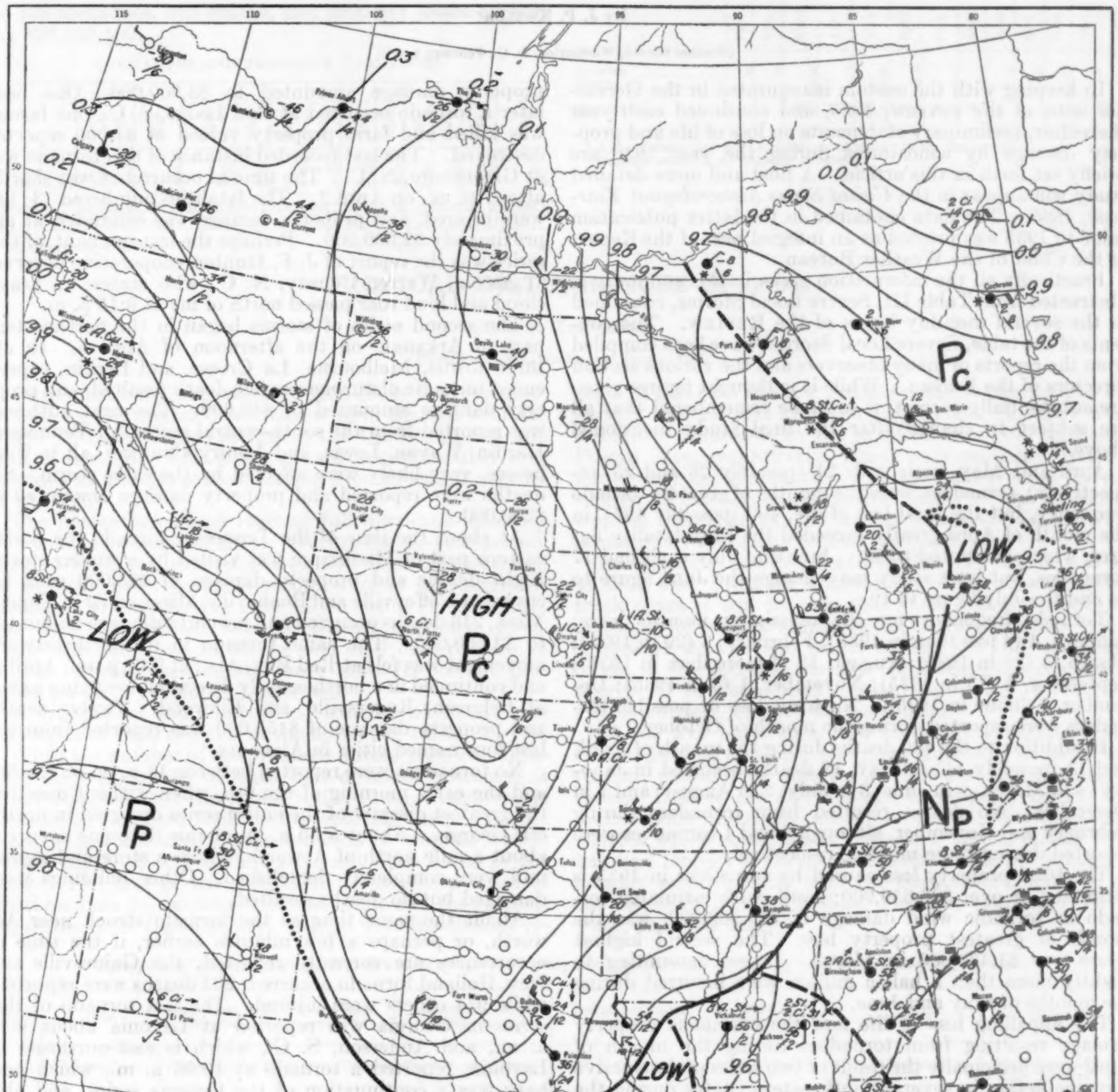
$N_P \rightarrow T_M$
2 A. M.
FEBRUARY 14, 1936


HIGH
Pc
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Pc
LOW
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LOW
Npp
Np → Tm
8 A.M.
FEBRUARY 14, 1936

PRELIMINARY REPORT ON TORNADOES IN THE UNITED STATES DURING 1936

By J. P. KOHLER

[Weather Bureau, Washington, D. C., February 3, 1937]

In keeping with the custom inaugurated in the December issue of the REVIEW, 1925, and continued each year thereafter, preliminary statements on loss of life and property damage by windstorms during the year 1936 are briefly set forth in this article. A final and more detailed study will appear in the *United States Meteorological Yearbook, 1936*. The data contained in the latter publication prior to 1935 was printed as an integral part of the Report of the Chief of the Weather Bureau.

Practically all the information given in this summary is abstracted from Table III, Severe Local Storms, contained in the several monthly issues of the REVIEW. The contents of the table, Severe Local Storms, have been compiled from the reports of many observers and the various section directors of the Bureau. While it is thought figures given are substantially correct, it must be remembered that all are subject to change after the final study mentioned above.

April and May, each with 21 (possibly 26 and 25, respectively), tornadoes, were the months of greatest tornado frequency, but the total loss of life, 490 (possibly 497), in the month of April greatly exceeded the May fatality figures, which amounted to 13. June and July each had 17 tornadoes, but later study may change the June figure to 24 and the July figure to 19.

Tornado frequency for the remaining months were: January, 4 (6 less than in 1935); February, 3 (29 in 1935); March, 5 (26 in 1935); August, 12 (4 more than in 1935); September, 5 (13 in 1935); November, 1 (3 in 1935); December, 7 (none in 1935). No tornadoes or possible tornadoes were reported during the month of October.

In addition to the 490 deaths during the month of April, and 13 (possibly 14) in May, 18 deaths occurred in January; 4 in March; 9 in June; 3 in July; 2 in August; and 1 in December. No deaths resulted from tornadoes during February and November, although 3 and 1 tornadoes were reported during these months, respectively.

The total property loss caused by tornadoes in 1935 is estimated at over $26,659,900; April, with estimated tornado or tornadic wind damage of $23,509,000, was the month of greatest property loss. The second highest figure was $1,432,000 in March. Losses amounting to slightly more than a half a million were incurred during the months of May and June.

The appalling loss of life and the enormous property damage resulting from tornadoes during the month of April were principally the result of two series of destructive tornadic action in several Southeastern States during the first week of the month.[1]

The first series of tornadoes began about 8:30 p. m., April 1, at Tignall, Ga. At 9 p. m., Lincolntown, Ga., about 17 miles southeast of Tignall, reported a tornado, and 50 houses, more or less, were wrecked or demolished. The next reported tornadic action came from Sasser, Ga., about 6 a. m., April 2. At 7:30 a. m. most likely the same storm struck Leesburg, Ga., which is located 10 miles east of Sasser, Ga., and the storm continued on to Cordele, Ga. One death was reported from each of the two towns, Sasser and Leesburg, Ga., with $3,000 and $4,300 property damage, respectively. The storm was unusually destructive at Cordele, Ga.; 23 persons were killed, 500 injured, and property damage amounted to $3,000,000. One hour later a tornado occurred at Red Lodge, S. C., one farmer was killed and farm property valued at $1,000 reported destroyed. The last recorded instance of this tornado was at Greensboro, N. C. The time of occurrence was shortly after 7 p. m., on April 2. The fatalities numbered 13; 144 were injured, and property damage was estimated at approximately $2,000,000. Perhaps the last remnant of this series was the report of J. F. Hunter, cooperative observer at Arcola, Warren County, N. C., who states: "a heavy cloud and loud roar passed north of me at 9:15 p. m."

The second series of storms began in the northeastern part of Arkansas on the afternoon of April 5. In all, three towns, Melbourne, La Crosse, and Larkin, experienced tornadic disturbances; one death resulted, and property damage amounted to $40,000. The next outbreak was reported from the south-central section of Tennessee; Hardin, Wayne, Lewis, and Maury Counties, all in Tennessee, very likely were affected by the same storm. Six deaths were reported and property damage amounted to $200,000.

At about the time of the Tennessee tornado the northeastern part of Mississippi was visited by a similar storm. Eight deaths and property damage of $35,000 were incurred at Coffeyville and Booneville, Miss., while at Tupelo, Miss., 216 deaths occurred and property damage amounted to $3,500,000. The same tornado in its northeastward movement was felt at Red Bay, Ala., at 9:02 p. m., April 5, and continued in a northeasterly direction, incurring havoc at Belgreen, Rogersville, and Elkwood. Twelve deaths and property damage of $155,000 was reported from the last four named cities in Alabama.

No tornadoes were reported between 11 p. m. on the 5th and the early morning of the 6th, when without question the greatest disaster of the entire series occurred in northern Georgia. About 8:30 a. m. of this date one occurred about a mile north of Acworth, where a store and a grist mill were completely demolished. Other buildings were damaged but no deaths resulted.

About the same time as the tornado struck near Acworth, or perhaps a few minutes earlier, if the time of occurrences are correctly reported, the Gainesville and New Holland tornado occurred; 203 deaths were reported, while 934 others were injured. The last tornado of this series in Georgia was reported at Lavonia about 9:30 a. m., and Anderson, S. C., which is east-northeast of Lavonia, reported a tornado at 10:05 a. m., which perhaps was a continuation of the Georgia series, and also the last reported instance.

According to J. B. Kincer of the Weather Bureau, who made a very detailed study of the series, as well as other notable tornado disasters in the United States "the group of tornadoes comprised by these two series, considering the number of people killed and injured and the property damage, probably ranks third in destructiveness in the tornadic history of the United States." In general, in the first series of April 1–2, about 41 persons were killed and 540 injured; in the second, April 5–6, some 452 persons were killed and 1,775 were injured.

The total number of tornadoes during the year, approximately 113, was 69 less than in the preceding year. The total number of deaths resulting from the 1936 storms were estimated at 540, which is 372 above the average.

[1] For more detailed description see "Tornado Disasters in the Southeastern States". by J. B. Kincer, MONTHLY WEATHER REVIEW, May 1936.

If further study shows the storms listed in the table of tornadic winds to be true tornadoes, the 1936 number will be 135 tornadoes, 550 deaths, and property losses exceeding $26,902,500.

TORNADOES AND PROBABLE TORNADOES

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Number	4	3	5	21	21	17	17	12	5	0	1	7	113
Deaths	18	0	4	490	13	9	3	2	0	----	0	1	540
Damage [1]	53.5	33.0	1,381.5	23,483.3	504.0	522.9	230.7	170.2	44.8	----	75.0	158.0	26,656.9

[1] In thousands of dollars.

TORNADIC WINDS AND POSSIBLE TORNADOES [2]

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Number	0	0	3	5	4	7	2	1	0	0	0	0	22
Deaths	----	----	0	7	1	2	0	0	----	----	----	----	10
Damage [1]	----	----	50.5	25.8	20.2	124.1	25.0	([3])	----	----	----	----	245.6

[2] Some of these may not be classed as tornadoes in the final study.
[3] Damage occurred, no estimate obtained.

TROPICAL DISTURBANCES OF 1936

By I. R. TANNEHILL

[Weather Bureau, Washington, January 1937]

During the hurricane season of 1936 (June to November, inclusive), 17 tropical disturbances were charted over the North Atlantic Ocean, including the Caribbean Sea and Gulf of Mexico. This is the second largest number ever recorded in a single season, having been exceeded only by 21 in 1933.

The percentage which reached full hurricane intensity was unusually small in 1936. During the 50-year period, 1887 to 1936, inclusive, slightly more than 50 percent of all tropical disturbances of record were of full hurricane intensity, whereas during 1936 only 5 out of 17, or slightly less than 30 percent, were of known hurricane force. There was only one hurricane out of 6 disturbances in August; during that month more than 70 percent normally are fully developed hurricanes.

A synopsis of the outstanding features of the 17 disturbances of 1936 is given in the appended table.

While the number of disturbances during 1936 was unusually large and many of them were of minor character, it is not believed that the excess is due in any considerable measure to increased facilities for reporting them. In fact there were three disturbed conditions in tropical waters during the 1936 season that have not been listed in the table. The first of these reached the southern coast of Haiti on June 24, causing some loss of life and the grounding of the S. S. *Baron Ogilvy*. There were insufficient reports in this case to show definite cyclonic character. On July 12 and 13, and again on July 21 and 22, there were disturbed conditions in the southwestern Gulf and near Puerto Rico, respectively, which were probably cyclonic but of very mild character. On the whole it must be considered an extraordinarily active season for the genesis of tropical disturbances, but one in which conditions were infrequently favorable for full development.

In respect to another feature, also, the season was an unusual one: From an examination of the accompanying track chart it will be seen that there was a remarkable deficiency of tropical storms in the Caribbean Sea. While it appears that several which crossed the Gulf had their origin in the extreme western Caribbean, the courses of nearly all of the season's disturbances lay wholly, or almost entirely, outside the Caribbean.

Of the five hurricanes, two crossed the coasts of the United States, and one, the great hurricane of mid-September, passed very near the Middle and North Atlantic coast. Loss of life and damage to property during the season were relatively small, however. Warnings and advices which were timely, frequent, and accurate, contributed largely to the preservation of life and property, notably in connection with the September hurricane on the coasts of North Carolina, Virginia, Maryland, Delaware, and New Jersey.

Synopsis of tropical storms 1936 (number of storm in table corresponds with number of track on accompanying chart

Storm	Date	Place where first reported	Coast lines crossed	Maximum wind velocity reported	Lowest barometer reported	Place of dissipation	Intensity	Remarks
I	June 11-17	Bay of Honduras	Mexico, Florida.	Force 9, on 2 steamships.	29.46, S. S. *Duquesne*	North Atlantic	Not of hurricane intensity.	Probably crossed Central America from Pacific. A.
II	June 19-21	Near Yucatan	Mexico	Force 8, S. S. *Cayo Mambi*.	29.52, S. S. *Cayo Mambi*.	Mexico	do	
III	June 26-27	Gulf, east of Brownsville.	Texas	80,[1] WNW., Port Aransas.	29.16, fishing vessel *Sea Gull*	Southern Texas.	Probably of hurricane intensity.	Property damage $550,000. A.
IV	July 26-28	Near western Cuba.	Louisiana	50,[1] at Delta Farms, La.	29.62, Delta Farms, La.	Mississippi	Not of hurricane intensity.	B.
V	July 27-Aug. 1	Southeastern Bahamas.	Florida	90-100,[1] ENE., Valparaiso, Fla.	28.73, Valparaiso, Fla.	Alabama	Hurricane	Property damage $150,000. B.
VI	Aug. 4-9	Near 20° N., 60° W.	Newfoundland			North Atlantic	Minor	
VII	Aug. 8-12	Gulf, south of Louisiana.	Mexico			Mexico	Not of hurricane intensity.	
VIII	Aug. 15-19	Gulf, near Yucatan Channel.	do	Force 9, S. S. *Cauto*	29.56, S. S. *Cauto*	do	Doubtful, but near hurricane intensity.	
IX	Aug. 20-22	Bahamas	Florida	55, SW., Titusville, Fla.	29.60, Titusville, Fla.	Middle Gulf Coast.	Not of hurricane intensity.	C.
X	Aug. 28-30	Near east coast of Yucatan.	Mexico	Force 11, S. S. *Cayo Mambi*.	29.52, S. S. *Cayo Mambi*	Mexico	Doubtful but near hurricane intensity.	
XI	Aug. 28-Sept. 5.	Near 17° N., 43° W.	None	Force 12 S. S. *West Lashaway*.	28.32, S. S. *Nike*	North Atlantic	Hurricane	D.
XII	Sept. 7, 8	Near 20° N., 55° W.	do			Near 22° N., 65° W.	Minor	

[1] Estimated.

Synopsis of tropical storms 1936 (number of storm in table corresponds with number of track on accompanying chart)—Continued

Storm	Date	Place where first reported	Coast lines crossed	Maximum wind velocity reported	Lowest barometer reported	Place of dissipation	Intensity	Remarks
XIII	Sept. 8-26	Near 13° N., 50° W.	Passed near Cape Hatteras.	80, NW., Hatteras	28.49, S. S. *Limon*	North Atlantic	Hurricane	A violent hurricane of large diameter; damage $1,600,000. D.
XIV	Sept. 11-13	Bay of Campeche.	Texas	Force 8, S. S. *Nemaha*	29.54, Brownsville	Southern Texas.	Not of hurricane intensity.	D.
XV	Sept. 19-24	Near 20° N., 62° W.	Nova Scotia	Force 12, S. S. *Saramacca.*	28.94 S. S. *Saramacca*	Nova Scotia	Hurricane	D.
XVI	Sept. 25-Oct. 1	East of Florida	Florida			Off New England coast.	Minor	
XVII	Oct. 9, 10	Bay of Campeche.	Mexico			Mexico	do	

More complete reports in MONTHLY WEATHER REVIEW: (A) June 1936; 64: 204, 205. (B) July 1936; 64: 238, 239. (C) August 1936; 64: 267, 268. (D) September 1936: 64: 297-299

EXTRATROPICAL DISTURBANCE IN LOW LATITUDES OF MID-ATLANTIC, DECEMBER 1936

By JEAN H. GALLENNE

[Marine Division, Weather Bureau, Washington, January 1937]

A disturbed condition, which appeared over the eastern Atlantic near the twenty-fifth meridian at about 30° N., on December 4, pursued an unusual course and attained considerable force on the 7th in mid-Atlantic. The track of the center of this disturbance is given on chart XI. Reports do not clearly show its movement from the 6th to 7th (dotted portion of track), and the center shown by observations on chart X may have been a fresh development. Its subsequent course to the south-southwestward carried it to low latitudes (apparently south of the twentieth parallel) on the 9th, after which it recurved and moved northwestward before dissipating on the 12th.

Pressure attending this disturbance was unusually low for the latitude and season; and the interruption of the trade winds over a considerable area was noted in many vessel weather reports. During this time the Atlantic anticyclone was well developed, but lay north and east of its usual position.

In fact, a ship report of 30.89 inches on December 8 at 44.5° N., 18.2 ° W. indicates an abnormal development and position of the Atlantic anticyclone. By the time the disturbance had dissipated, the anticyclone had assumed a position farther west than normal, with unusual development—pressure 30.74 inches on December 12.

At the time of the first appearance of the disturbance, observations from a number of ships indicated that barometric pressure over the North Atlantic Ocean in the vicinity of 31° N. and 32° W., was considerably below normal. A fairly well developed cyclonic wind circulation existed at 7 a. m. of the 5th. The Dutch steamship *Venezuela* at 9:32 a. m. (local mean time) of the 5th, when near 31° N. and 37° W., reported wind of force 6 from the west, barometer reading 29.87 inches. Winds of force 8 were also reported from ships in the northerly quadrant of the depression, on that date.

Progressing in a northwesterly direction during the next 24 hours, this disturbance was centered near 33° N. and 35½° W. at 7 a. m. (e. s. t.) of December 6. On the morning of that day, it appeared to be moving into a LOW trough which extended to the north-northwestward toward Julianehaab, Greenland; but due to the southwesterly trend of high pressure, which had overspread the northern portion of the Atlantic Ocean, its course was directed more to the westward.

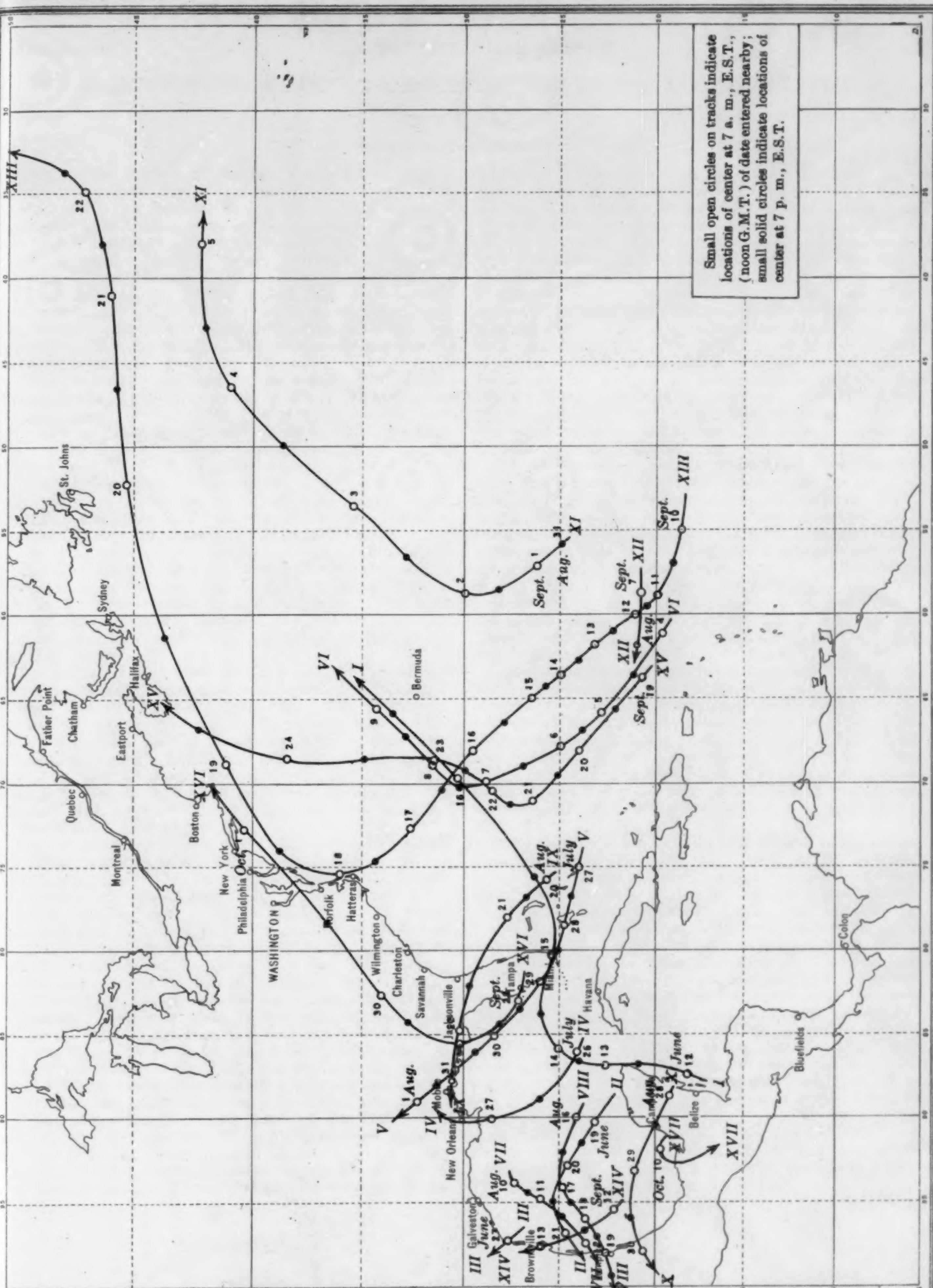
The Italian steamship *Clara* at 9:50 a. m. (local mean time) December 6, when near 33° N. and 33¼° W. reported SSE. winds of force 5, rough sea, barometer reading 29.74 inches. This same vessel subsequently reported that at noon, near 33° N. and 33°40′ W., SSE. winds of force 7 were encountered and that the barometer was falling. During the afternoon the wind shifted through S. to SSW., increasing to force 9–10, accompanied by a very high sea. The barometer continued to fall until 4 p. m. The barometric minimum, 29.41 inches (corrected), occurred at that time; the vessel reported her position to be 32°59′ N. and 33°58′ W.

Fresh to high winds were encountered by several ships near the path of the disturbance during the 6th. On the morning of the 7th, the British motorship *Benedick* at 8:42 a. m. (l. m. t.) when near 32°43′ N. and 49°23′ W., reported squally weather with NNW. wind of force 9 and a barometer reading of 29.65 inches. High winds accompanied by rain were also experienced on the 7th by vessels near the center of the disturbance at latitude 32° N. and 47° W. (chart X).

The steamship *West Irmo* noted whole gales from the NNE., with barometer reading 29.77 inches, on the morning of the 8th, when near 26° N. and 56° W. At the p. m. observation of the 8th this same vessel when near 24½° N. and 54½° W., reported NE. wind, force 8; barometer 29.74 inches. The disturbance was then moving south-southwestward.

During the period of recurve on December 9 and thereafter until the disturbance dissipated on the 12th near 25° N., 53° W., ships' reports do not indicate that there were any winds of gale force.

Paths of Hurricanes and Other Tropical Storms, 1936
(Plotted by J. H. Gallenne)



DUSTSTORMS OF AUGUST–DECEMBER 1936 IN THE UNITED STATES

By R. J. MARTIN

[Weather Bureau, Washington, January 1937]

Despite the dryness of the last 5 months of 1936 in much of the Great Plains area and the Southwest, duststorms were less frequent and decidedly less severe in character than during some of the preceding months of the year. But while rainfall totals in September averaged from 118 percent to 253 percent of normal in Arizona, Colorado, New Mexico, Kansas, Texas, and Oklahoma, and portions of the States named had above-normal amounts in August, October, November, and December, occasional storms occurred during the autumn and through December, showing that in some southwestern areas the drought is still unrelieved.

While August rainfall was decidedly subnormal in most Plains States and the Southwest, with totals in large areas ranging from less than 10 to 25 percent of normal, duststorms were fewer than in several other months of 1936. Only a few duststorms were reported, and the frequency seldom exceeded 6 for the month, ranging from 3 or less in the southern Great Plains to about 10 locally in the more northern Plains States. They were most frequent from the 16th to the 23d, though there were a few isolated occurrences early in the month and near the close.

Dust was reported from Idaho eastward to Illinois, and from Oklahoma northward, but only rarely did it reduce visibility to a marked degree, the general average of minimum visibility being from 2 to 5 miles. The most severe local duststorm occurred at Boise, Idaho, on August 2, when visibility was reduced to 25 feet or less for short intervals.

The storms of September were mostly light in character though occasional dense dust was reported in Montana, North Dakota, Nebraska, Colorado, and Oklahoma. Light dust was noted over most western sections from Texas and New Mexico northward and in the upper Mississippi Valley. Light dust was general in eastern Montana and Colorado and in Nebraska and South Dakota. The storms were scattered throughout the month, being reported in each week, but were most frequent from the 17th to the 29th.

The visibility was seldom less than 2 miles, but during the dense storms in those States mentioned above it was considerably less. The first dense storm of the month was reported at Cloud Chief, Okla., on the 1st, where the visibility was reduced at times to 5 yards. Between 4:20 and 4:25 p. m. on the 12th dense clouds of dust about 2,000 feet high were noted along the foothills northeast of Helena, Mont., but only light dust was reported in the city. In northeastern Colorado the storm of the 25th reduced visibility to 300 yards, and at 6:30 p. m. in Denver it was zero while by 9 p. m. the storm had moved on to Pueblo where the visibility was less than one city block; the airport at the latter station reported a maximum wind velocity of 50 miles per hour during this storm. On the same date dense dust occurred at Lincoln, Nebr. Farther north Bismarck, N. Dak., reported a visibility of one-fourth mile at times on the 13th. The dust reported in Colorado on the 23d–25th blew in from the Navajo Indian Reservation in Utah.

During October duststorms were reported from eastern New Mexico and the Texas Panhandle northward to the Canadian Border, and from the Rocky Mountain States eastward to the middle Mississippi Valley and the Lake region. The storms were generally of light intensity and short duration, and were most frequent on October 9, 10, 17, 20, 28, and 30. On the 30th these storms were general in North Dakota and widespread storms occurred during the month in eastern Montana and South Dakota. The storms of the 30th were classified as the worst of the season in eastern South Dakota; at Huron the visibility was reduced to 1,300 feet, and at Moorhead, Minn., the dust on the 30th was dense from 1 p. m. to 5 p. m., with visibility reduced to one-fourth mile the greater part of the afternoon. Only a few dense occurrences other than the above were reported; in most cases visibility during the height of the storms ranged from 1½ miles to 7 miles. The dust reported at Madison, Wis. was apparently brought from the Dakotas.

During November dust was widespread, being reported from Port Arthur, Tex., to the Canadian Border and from the Rocky Mountains eastward to Chattanooga, Tenn., and Buffalo, N. Y. Most of the storms occurred late in the month, generally from the 19th to the 25th, and ranged in frequency from only one occurrence at some stations to six or more at others, the greatest number being reported in the central and northern Great Plains. Dust was encountered at various altitudes by aviators, the height of the clouds ranging upward to 4,000 feet east of Wichita, Kans., and 6,000 feet at Chicago, Ill., where the visibility was reduced to 3 miles.

General storms were reported in Iowa and the Dakotas, eastern Colorado and New Mexico, Missouri, southwestern Wisconsin, eastern Montana, and eastern Nebraska. In portions of North Dakota street lights were necessary at times when visibility was least. In central South Dakota and portions of Iowa the storms were the worst in 2 years. In general, minimum visibility in the densest storms was one-half mile, but in portions of Nebraska it was reduced to one-fourth mile on the 22d, and to 100 yards on the 24th.

Light dust was reported in the Plains States during December from Oklahoma northward, in some Rocky Mountain sections, and in portions of the upper Mississippi Valley, the frequency ranging from 6 days in the southern plains to 2 or less in the north. On the 28th and 29th the visibility in Baca County, Colo., was reduced to from 50 feet to one-half mile at times from 9 a. m. to 3 p. m. In Sierra, Valencia, and Luna Counties, New Mexico, visibility on the 16th–17th was reduced to 100 feet by local duststorms, and on the 23d rather severe local storms in Roosevelt, Lea, and Eddy Counties reduced visibility to one-half mile from 11 a. m. to 4 p. m. In plains sections of Mora, Colfax, Harding, and Union Counties, New Mexico, visibility was reduced to 100 feet on the 30th from 9 a. m. until sunset. Much topsoil was blown from fields, and in Colfax County it was the most severe storm in several years.

In North Dakota light dust was general on the 19th, and several storms occurred in central Montana where Geraldine (near) reported a "terrific duststorm" from 6 p. m. of the 19th to 3 a. m. of the 20th.

123291—37——3

ON THE COMPUTATION OF ATMOSPHERIC TURBIDITY AND WATER VAPOR FROM SOLAR RADIATION MEASUREMENTS—A CORRECTION TO PREVIOUS NOTE

In a paper in the REVIEW for November 1936, page 377, appears the following statement:

I was greatly shocked when I discovered that the mean of values derived from $I_v - I_r$ and from $I_m - I_v$ had been employed in determining the values of β for dry air. I very much regret this error for which I assume full responsibility.

However, at a conference with my former associates at the Weather Bureau, it has now been made clear that the supposed erroneous method was correct. Therefore, no corrections are necessary to earlier computed values of β.

In computing values of β from $I_v - I_r$, I made use of a method that Hoelper has criticised on the ground that $I_v - I_r$ is too small a number to give accurate results. In this case, however, after November 15, $I_v - I_r$ had been measured by a very accurate instrument. It is, therefore, believed that the value derived from $I_v - I_r$ may be accepted as reasonably correct.

Beginning with January 1937, curves published by Hoelper in the *Deutschen Meteorologischen Jahrbuch* for 1933, and which Feussner recommends, will be employed in the United States in computing both β and w by the method now followed at European observatories, except that for the present, at least, we shall compute w from the difference between I_m (dry) and I_m (observed).—*H. H. Kimball.*

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[RICHMOND T. ZOCH, *in Charge of Library*]

By AMY D. PUTNAM

RECENT ADDITIONS

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SOLAR OBSERVATIONS

SOLAR RADIATION MEASUREMENTS DURING DECEMBER 1936

By IRVING F. HAND, Assistant in Solar Radiation Investigations

For a description of instruments employed and their exposures, the reader is referred to the January 1935 REVIEW, page 24.

Table 1 shows that solar radiation intensities averaged below normal at Washington and Madison, and slightly above normal at Lincoln.

Table 2 shows a deficiency in the amount of total solar and sky radiation received on a horizontal surface at all stations with the exception of Madison, Fresno, New York, and Twin Falls. The percentage departures for the year show that all stations had an excess with the exception of Twin Falls, Miami, Riverside, and Blue Hill.

Beginning with this issue table 3 appears in a slightly different form containing two new columns, thus enabling the reader to better follow the method of computation. On the computation of β and w, see the November REVIEW, p. 377, and this REVIEW, p. 430.

Polarization observations obtained at Washington on 6 days give a mean of 55 percent with a maximum of 60 percent on the 5th. At Madison observations were obtained on 2 days only, the 4th and 31st, with values of 54 and 64 percent, respectively. All of these values are slightly below the corresponding normals for December.

TABLE 1.—*Solar radiation intensities during December 1936*

[Gram-calories per minute per square centimeter of normal surface]

WASHINGTON, D. C.

Date	Sun's zenith distance										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A. M.				[1] 1.0	P. M.				
	e	5.0	4.0	3.0	2.0		2.0	3.0	4.0	5.0	e
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Dec. 1	1.07	0.83	0.96	1.10	------	------	------	------	------	------	1.78
Dec. 4	4.57	.49	.68	.83	1.12	------	------	------	------	------	4.75
Dec. 5	2.74	.68	.87	1.07	1.24	------	------	------	------	------	2.49
Dec. 8	1.68	------	1.02	------	1.35	------	------	1.01	------	------	1.37
Dec. 17	6.27	.74	.87	1.00	1.10	------	------	------	------	------	5.56
Dec. 21	2.62	.85	.95	1.16	1.32	------	------	------	------	------	2.36
Dec. 22	2.26	.64	.75	.88	1.12	------	------	.89	0.76	0.63	2.36
Dec. 24	3.00	.79	.88	1.04	1.21	------	------	------	------	------	3.63
Means	------	.72	.87	1.01	1.21	------	------	(.95)	(.76)	(.63)	------
Departures	------	−.06	−.03	−.04	−.02	------	------	−.09	−.06	−.04	------

MADISON, WIS.

Date	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
Dec. 4	1.52	1.00	1.18	1.29	------	------	------	------	------	------	1.32
Dec. 8	1.88	------	.56	.86	------	------	------	------	------	------	2.06
Dec. 11	.71	1.04	1.13	1.30	------	------	------	0.96	0.54	------	.96
Dec. 23	3.15	.68	.80	1.03	------	------	------	1.00	------	------	3.81
Dec. 31	1.96	------	------	1.20	------	------	------	------	------	------	1.96
Means	------	.91	.92	1.14	------	------	------	(.98)	(.54)	------	------
Departures	------	−.05	−.16	−.07	------	------	------	−.27	−.48	------	------

[1] Extrapolated.

TABLE 1.—*Solar radiation intensities during December 1936*—Contd.

LINCOLN, NEBR.

Date	Sun's zenith distance										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A. M.				[1] 1.0	P. M.				
	e	5.0	4.0	3.0	2.0		2.0	3.0	4.0	5.0	e
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Dec. 3	3.00	0.96	1.19	1.32	------	------	------	------	1.08	0.98	3.45
Dec. 10	2.16	.96	1.11	1.27	------	------	------	------	1.10	1.03	1.32
Dec. 11	2.06	.99	1.08	1.23	------	------	------	------	------	------	3.30
Dec. 16	3.99	1.03	1.14	1.30	------	------	------	------	------	------	4.37
Dec. 22	2.62	------	------	------	------	------	------	1.07	.91	.80	3.15
Dec. 23	3.45	.98	1.07	1.26	------	------	------	1.16	------	------	4.57
Means	------	.98	1.12	1.28	------	------	------	(1.12)	1.03	.94	------
Departures	------	+.04	+.03	+.05	------	------	------	+.08	+.04	+.02	------

BLUE HILL, MASS.

Date	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
Dec. 1	1.1	0.83	0.95	1.07	------	------	------	------	------	------	1.5
Dec. 4	4.2	------	------	------	------	------	------	------	1.07	1.00	3.2
Dec. 5	2.0	1.01	1.11	1.23	1.36	------	------	1.17	1.02	.88	1.8
Dec. 8	.9	.94	1.08	1.12	------	------	------	------	------	------	2.8
Dec. 14	2.2	------	------	------	------	------	1.34	1.20	1.08	.98	3.2
Dec. 15	3.2	.81	.87	.88	------	------	1.17	1.17	------	.88	3.3
Dec. 17	6.1	------	------	------	------	------	1.25	1.08	.84	------	3.0
Dec. 18	1.5	1.10	1.16	1.25	1.38	------	1.38	1.25	1.16	1.06	1.3
Dec. 21	2.9	------	------	1.15	1.40	------	1.40	1.20	.96	------	2.3
Dec. 22	1.6	------	1.12	1.23	1.43	------	1.43	1.26	1.12	------	.9
Dec. 23	1.1	------	------	1.27	1.41	------	1.41	1.28	1.13	1.08	1.4
Dec. 28	7.9	------	------	1.13	1.24	------	1.29	1.36	1.29	1.18	3.2
Dec. 29	1.6	------	------	------	1.36	------	1.36	1.32	1.25	1.16	2.6
Means	------	.94	1.05	1.15	1.37	------	1.34	1.23	1.09	1.03	------

TABLE 2.—*Average daily totals of solar radiation (direct+diffuse) received on a horizontal surface*

Week beginning—	Gram-calories per square centimeter														
	Washington	Madison	Lincoln	Chicago	New York	Fresno	Twin Falls	La Jolla	Miami	New Orleans	Riverside	Blue Hill	San Juan	Friday Harbor	Ithaca
1936	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Dec. 3	120	122	139	78	118	204	123	258	200	156	225	99	456	54	80
Dec. 10	102	155	213	119	113	181	140	200	275	44	187	100	458	85	84
Dec. 17	162	142	140	109	120	66	126	249	290	281	244	160	419	59	80
Dec. 24	159	137	106	68	130	128	102	176	268	147	166	114	289	72	83
	Departures from weekly normals														
Dec. 3	−39	+6	−33	+9	+16	+13	+12	----------	−5	−16	+12	−31	----------	−26	−1
Dec. 10	−34	+42	+47	+79	+12	+2	+21	----------	−33	−140	−30	−28	----------	+10	+2
Dec. 17	+17	+22	−38	+21	+32	−83	+9	----------	+10	+91	+21	+18	----------	−12	−11
Dec. 24 [1]	+10	+14	−68	−17	+15	−10	−31	----------	−15	−21	−54	−34	----------	+4	−17
	Accumulated departures on—														
	+5,152	+4,564	+7,707	+11,613	+8,379	+4,550	−2,576	----------	−8,827	----------	−1,246	−1,638	----------	+1,281	+987
	Percentage departure for year														
	+4.4	+3.8	+5.6	+18.0	+8.2	+2.7	−1.8	----------	−5.7	----------	−0.8	−1.3	----------	+0.8	+0.8

[1] 8-day means.

ON THE METHOD EMPLOYED FOR COMPUTING β AND W, SEE P. 430 OF THIS REVIEW.—ED. •

TABLE 3.—*Total, I_m, and screened, I_y, I_r, solar radiation intensity measurements, obtained during December 1936 and determinations of the atmospheric turbidity factor, β, and water-vapor content, w=depth in millimeters, if precipitated*

AMERICAN UNIVERSITY, WASHINGTON, D. C.

Date and hour angle	Solar altitude	Air mass	I_m	I_y	I_r	(*) $\frac{I_y}{0.851+C}$	(*) $\frac{I_r}{0.840+C}$	βI_{y-r}	(*) $\frac{I_{w-s}}{1.94}$ Percentage of solar constant	(*) $\frac{I_{w-s}-I_m}{1.94}$ Percentage of solar constant	w	Air-mass type
1936												
Dec. 4	° ′	m	gr cal.	gr cal.	gr cal.	gr cal.	gr cal.				mm	
1:04 a. m.	27 00	2.20	1.042	0.760	0.633	0.864	0.729	0.118	58.7	6.5	2.2	Pc
0:56 a. m.	27 25	2.17	1.063	.764	.637	.869	.733	.118	59.1	5.9	1.9	
Dec. 5												
1:20 p. m.	25 53	2.29	1.197	.907	.745	1.031	.857	.059	69.4	9.5	5.2	Pc
1:28 p. m.	25 19	2.33	1.191	.905	.746	1.030	.858	.060	69.6	10.0	6.9	
Dec. 8												
3:05 a. m.	14 56	3.84	1.039	.822	.686	.932	.787	.044	62.1	10.2	4.8	Pc
2:58 a. m.	15 36	3.68	1.083	.824	.688	.935	.789	.046	62.6	8.4	2.8	
1:20 p. m.	25 36	2.31	1.196	.883	.710	1.001	.815	.046	71.6	11.8	14.0	
1:25 p. m.	25 09	2.35	1.170	.885	.712	1.003	.818	.044	71.4	12.9	21.0	
Dec. 21												
2:58 a. m.	15 07	3.80	.985	.749	.630	.848	.722	.053	59.3	10.2	4.7	NP
2:55 a. m.	15 26	3.72	.971	.755	.634	.854	.727	.068	57.3	8.8	3.1	
0:49 a. m.	26 36	2.23	1.282	.944	.776	1.070	.890	.066	70.5	6.6	2.3	
0:45 a. m.	26 48	2.22	1.295	.944	.776	1.070	.890	.055	70.6	6.0	1.9	
Dec. 22												
3:12 a. m.	13 10	4.32	.699	.600	.521	.678	.596	.100	43.9	9.1	3.1	Pc
3:07 a. m.	13 50	4.12	.703	.609	.530	.689	.606	.104	44.7	9.6	3.7	
0:58 p. m.	26 11	2.26	1.052	.811	.681	.918	.780	.110	59.8	7.3	2.8	
1:01 p. m.	26 02	2.28	1.073	.807	.677	.915	.777	.106	60.0	6.5	2.2	
Dec. 24												
3:05 a. m.	14 06	4.04	.863	.699	.574	.791	.657	.050	58.8	15.8	38.0	NP
3:02 a. m.	14 30	3.94	.871	.709	.584	.802	.669	.055	58.2	14.8	28.0	

Atmospheric conditions during turbidity measurements

* Values reduced to mean solar distance.
Dec. 4. Temperature 3° C.; wind, NW 12; polarization, 53 percent; visibility, 20 miles; sky blueness, 5.
Dec. 5. Temperature 1° C.; wind, N. 12; polarization, 60 percent; visibility, 50 miles; sky blueness, 6.
Dec. 8. Temperature−4° C.; wind, N. 9; polarization, 51 percent; visibility, 30 miles; sky blueness, 5.
Dec. 21. Temperature 0° C.; wind, W. 14; polarization, 58 percent; visibility, 30 miles; sky blueness, 6.
Dec. 22. Temperature−1° C.; wind, NW. 12; polarization, 54 percent; visibility, 12 miles; sky blueness, 5.
Dec. 24. Temperature 0° C.; wind, S. 5; polarization, 54 percent; visibility, 30 miles; sky blueness, 6.

BLUE HILL METEOROLOGICAL OBSERVATORY OF HARVARD UNIVERSITY

Date and hour angle	Solar altitude	Air mass	I_m	I_y	I_r	$\frac{I_y}{0.851+C}$	$\frac{I_r}{0.840+C}$	βI_{y-r}	$\frac{I_{w-s}}{1.94}$	$\frac{I_{w-s}-I_m}{1.94}$	w	Air-mass type
Dec. 1												
3:43 a. m.	7 21	----	0.688	0.518	0.468	0.593	0.538	----	----	----	----	
2:47 a. m.	15 19	3.74	.984	.604	.596	.763	.671	0.090	51.0	1.8	0.9	Pc
Dec. 4												
3:46 p. m.	8 00	----	.728	.518	.456	.588	.527	----	----	----	----	Pc
Dec. 5												
3:04 a. m.	12 45	4.47	1.058	.712	.608	.731	.697	.050	62.0	9.1	4.7	
1:20 a. m.	22 56	3.56	1.244	.841	.690	.967	.793	.061	68.1	8.9	3.2	Pc
0:27 a. m.	25 09	2.35	1.288	.868	.716	.986	.824	.072	66.3	1.8	1.0	
3:29 p. m.	9 32	----	.840	.618	.536	.726	.615	----	----	----	----	
Dec. 8												
3:19 a. m.	11 40	4.85	.928	.652	.560	.745	.639	.090	48.0	3.6	1.7	Pc
Dec. 14												
0:33 p. m.	29 12	2.05	1.264	.856	.708	.973	.813	.065	70.5	13.0	9.2	
2:07 p. m.	19 15	3.02	1.200	.820	.684	.939	.792	.064	62.0	2.0	1.2	NP
Dec. 15												
1:16 a. m.	22 13	2.13	.952	.656	.560	.740	.639	.152	48.0	.5	.3	
0:44 p. m.	22 45	2.48	1.060	.730	.604	.827	.693	.152	59.1	6.5	2.6	NP
3:49 p. m.	----	----	.640	.496	.424	.562	.487	----	----	----	----	
Dec. 17												
2:51 p. m.	13 27	4.25	.688	.496	.404	.561	.462	.080	49.0	4.1	2.0	NPC
Dec. 18												
1:57 a. m.	19 52	3.06	1.268	.808	.706	.914	.808	.113	51.8	11.0	6.3	
1:00 p. m.	22 24	2.63	1.400	.936	.760	1.060	.870	.024	75.5	5.6	3.5	Pc
2:48 p. m.	13 55	4.25	1.116	.784	.640	.894	.733	.027	66.4	10.9	5.4	
Dec. 21												
2:13 a. m.	15 13	3.77	1.104	.776	.638	.876	.730	.045	61.6	6.5	3.4	
2:02 p. m.	18 33	3.13	1.118	.808	.664	.912	.759	.065	61.3	2.5	1.4	NP
Dec. 22												
1:33 a. m.	21 06	2.68	1.296	.880	.724	.992	.826	.090	73.0	8.3	5.1	
0:19 a. m.	24 11	2.45	1.388	.936	.761	1.056	.869	.080	77.0	8.0	5.2	Pc
Dec. 23												
1:48 a. m.	19 46	2.93	1.296	.872	.720	.983	.800	.080	69.6	4.5	2.7	
0:20 a. m.	24 10	2.43	1.344	.888	.732	1.001	.834	.062	69.2	2.0	1.3	Pc
2:46 p. m.	13 57	4.74	1.104	.748	.700	.845	.807	.052	57.8	5.4	3.1	
Dec. 24												
1:58 a. m.	23 16	2.52	.914	.656	.558	.742	.639	.156	50.2	4.6	2.9	NP
Dec. 28												
1:45 a. m.	20 17	2.86	1.144	.784	.640	.888	.734	.062	66.4	6.0	3.6	
0:47 a. m.	23 35	2.49	1.240	.836	.680	.946	.781	.062	67.2	3.4	2.2	NP
Dec. 29												
0:44 a. m.	23 42	2.48	1.336	.802	.728	1.008	.832	.083	69.2	2.6	1.7	
12:00 noon	24 32	2.41	1.344	.892	.732	1.008	.837	.061	69.0	2.0	1.3	Pc

Atmospheric conditions during Smithsonian Observations December 1936

Date	Time from apparent noon	Temperature ° C.	Wind, Beaufort	Visibility	Sky blueness	Cloudiness and remarks
Dec. 1	3:36 a. m.	−13.1	NNW 3	6	6	Few Cu; moderate to dense haze; instrument indoors.
5	3:19 a. m.	−2.8	NW 4	7	9	Zero clouds; moderate haze; instrument indoors.
5	0:08 p. m.	+.7	NW 5	8	8	1 Ci; light haze; Frcu near sun.
8	3:26 a. m.	−11.3	NE 3	6	9	Trace Acu; dense haze.
14	1:15 p. m.	+1.3	SW 2	7	9	2 Ci; moderate haze; instrument outdoors.
15	1:52 a. m.	+4.1	W 4	6	8	Zero clouds; dense haze.
18	2:10 a. m.	−6.8	NW 5	9	10	Zero clouds.
22	0:53 a. m.	−5.6	NW 6	9	11	Trace Cu.
22	0:26 a. m.	−6.1	NW 5	9	11	Trace Cu and Frcu.
23	0:56 a. m.	−6.9	WNW 3	8	10	Trace Ci.
24	2:09 a. m.	+1.4	SW 4	5	8	2 Ci; dense haze.
28	1:20 a. m.	+8.3	WNW 6	8	10	Trace Cist; trace Cu; moderate haze.
28	0:35 a. m.	+8.3	WNW 6	8	10	Trace Cist; Trace Cu; moderate haze.
29	0:37 a. m.	+2.8	ENE 3	8	9	4 Ci, moderate haze to NE.

POSITIONS AND AREAS OF SUN SPOTS

Note.—The reports for November and December 1936, not having been received in time, will be included in the January 1937 issue of the REVIEW.—*Ed.*

PROVISIONAL SUN-SPOT RELATIVE NUMBERS, DECEMBER 1936

[Dependent alone on observations at Zurich and its station at Arosa]

[Furnished through the courtesy of Prof. W. Brunner, Eidgen. Sternwarte, Zurich, Switzerland]

December 1936	Relative numbers	December 1936	Relative numbers	December 1936	Relative numbers
1	*bdd* 193	11	*d* 82	21	*dd* 86
2	*b* ---	12	*Wc* 76	22	117
3	*a* ---	13	*d* 74	23	130
4	---	14	71	24	*Eaccd* 149
5	158	15	40	25	151
6	*Ec* 146	16	43	26	*a* 150
7	*aa* ---	17	*Wac* 70	27	*a* 151
8	*Ec* 134	18	*d* 88	28	*ad* 135
9	104	19	*a* 85	29	*Eacd* 167
10	*a* 107	20	74	30	*Eac* 200
				31	181

Mean, 27 days = 117.5.

a = Passage of an average-sized group through the central meridian.
b = Passage of a large group or spot through the central meridian.
c = New formation of a group developing into a middle-sized or large center of activity: E on the eastern part of the sun's disk; W, on the western part; M, in the central circle zone.
d = Entrance of a large or average-sized center of activity on the east limb.

AEROLOGICAL OBSERVATIONS

[Aerological Division, D. M. LITTLE, in charge]

By L. P. HARRISON

Mean free-air temperatures and relative humidities for December, as determined from airplane weather observations, are given in table 1. The "departures from normal" given in the table are based on "normals" derived from the number of observations indicated in the note at the foot of the table, where the numbers of years over which the observations were taken are given by the figures in parentheses. In general, the numbers of observations available for computing "normals" for the higher levels are less than those available for the lowest levels (represented by the data given in the footnote). To compensate for this discrepancy, the "normals" are obtained by applying the mean differences between the successive standard levels to the data for the lower levels, where the "normal" for the surface based on the indicated number of observations serves as the reference basis. The "normals" in each case include the data for the current month. It will be noted that many of the "normals" are based on only three years of observations. "Departures from normal" in such cases must be regarded as having little weight in comparison with departures from "normals" based on much more extended periods of record (35 or more years, say, which are not uncommon in climatology).

The mean temperatures for the month at the surface (see chart I) were above normal over practically the entire country. The greatest positive departures from normal temperature at the surface were to be found largely in the central part of the country, the southern portion of the Great Lakes area, the coastal strip extending approximately from Massachusetts to New Jersey, and also a small region from eastern Washington to western Montana. Departures in these areas generally were from +1.5° to nearly +3.5° C. Small regions of negative departure from normal were to be found in parts of northern and central California as well as eastern Montana.

The mean temperatures for the month in the free air (see table 1) were largely above normal in the eastern third, and in a portion of the central part, of the country. The greatest positive departures from normal temperature in the free air were largely concentrated in the area encompassed by the stations at Boston, Lakehurst, Mitchel Field, Scott Field, and Wright Field, where the departures for these respective places ranged as follows in the free-air levels for which data were available: +3.4° to 4.6° C., 2.6° to 5.5° C., 4.4° to 6.9° C., 1.4° to 3.8° C., and 2.7° to 4.7° C.

Negative departures from normal free-air temperatures during December were generally small in magnitude and were mostly confined to the western third of the country with extensions in the north-central and south-central areas. The negative departures were most pronounced at Spokane and San Diego (−0.8° to −3.5° C., and −1.1° to −2.3° C., respectively).

Mean monthly free-air relative humidities during the month under review were appreciably below normal in the eastern third of the country at all levels except those within 0.5 to 2 km of the ground in some cases, where above-normal humidities prevailed in a slight degree. The region of most marked negative departure from normal relative humidity could be identified with the region of greatest positive departures from normal of temperature referred to above. This condition was most pronounced in the levels from about 1.5 to 4 km above sea level, where departures as great as −16 to −18 percent occurred at Lakehurst, Mitchel Field, and Wright Field. (It is possible that these values are somewhat greater than they should be, owing to the lack of a full month's observations—19, 18, and 20 observations, respectively, being actually available—and the absence of data principally for days with low clouds, precipitation, etc.) The layer of marked subnormal humidities occurred at somewhat lower elevations in the southwestern portion of

the area under consideration than in the northeastern portion, as may be noted from the fact that the maximum negative departures were observed at 1.5 and 1.0 km at Wright Field and Scott Field, respectively, whereas they were observed at 4 and 3 km at Boston and Mitchel Field, respectively.

Mean free-air relative humidities for the month were above normal by rather slight amounts over the central portion of the country; below normal by significant amounts in the lowest kilometer over the north-central portion (note −6 to −11 percent at Fargo, N. Dak.); and practically normal above that layer, as well as practically normal in the south-central portion.

The mean monthly free-air relative humidities in the western third of the country generally exceeded the normals by moderate amounts. The most pronounced positive departures were to be found at San Diego and Spokane, where they ranged from +8 to +11 percent and +5 to +12 percent, respectively, in the layer 1.5 to 5 km above sea level.

The free-air resultant winds based on pilot balloon observations made near 5 a. m. (75th meridian time) during December are given in table 2. The region near to, and also to the east of, the Appalachian Mountain system as far as the Atlantic coast, was characterized by free-air resultant winds which were generally near normal in direction but sub-normal in velocity. The resultant winds at Atlanta in the 0.5 and 1 km levels are exceptions to this statement as may be seen by comparing the direction (azimuth from N.) and velocity (m. p. s.) values for the normal (in parentheses) and the month under review, respectively: (318°, 2.8) 68°, 3.1 (297°, 4.9) 79°, 1.9. In the region in question, negative departures from normal of the resultant velocity were quite considerable (>3 m. p. s.) in a number of cases within the layer from 1 to 3 km above sea level. At Boston and Washington, the departures were −5.0 and −6.1 m. p. s., respectively, at the 2.5 km level where the departures were most extreme.

At Key West, the resultant winds were near normal in direction and only slightly above normal in velocity.

Except near Sault Ste. Marie with regard to direction (so far as available data are concerned), the free-air resultant winds in the Great Lakes region were generally normal in direction but slightly above normal in velocity. This may also be extended to include Fargo, N. Dak. At Sault Ste. Marie the relationship which existed between the normal (in parentheses) and the month's resultant winds at the surface, 0.5, and 1 km levels, respectively, may be seen from the following data therefor: (49°. 0.2), 157°, 0.9 (273°, 1.5), 230°, 4.0 (292°, 3.1), 235° 6.6.

In the levels from about 0.5 to 1.5 km above sea level, especially in the lower part of this stratum, the monthly wind resultants for Oklahoma City, Murfreesboro, Cincinnati, St. Louis, and Omaha, were appreciably oriented from a more southerly component in direction than the normal by amounts varying from 0 to 80°. This condition was most pronounced at the southern stations. These stations generally had slight to moderate negative departures from normal resultant velocities, except Oklahoma City, where moderate positive departures prevailed from the surface to 1.5 km above sea level as exemplified by the following comparisons: (Normal in parentheses and month's resultant) 0.5 km (244,° 2.0), 190°, 5.5; 1 km (272°, 4.9), 231°, 8.4; 1.5 km (281°, 5.8), 249°, 6.6. The corresponding data for Houston are of interest: (187°, 2.1), 95°, 2.5 (244°, 3.5), 291°, 1.2 (267°, 5.0), 302°, 3.3. From 2 to 3 km, the resultants for this station were normal in direction but slightly below normal in velocity. It thus appears that there occurred a greater than normal transport of air up the Mississippi Valley in the lower levels, while at upper levels, the customary westerly drift was weakened.

In the plateau region, the resultant directions were near normal but the resultant velocities were generally above normal by slight amounts except up to about 2.5 km above sea level at Cheyenne and Billings (627 and 1,411 meters above ground, respectively), where they were below normal by slight amounts. Spokane had remarkable positive departures from normal velocity at the 1.5, 2.5, 3, and 4 km levels as may be seen from the following data: +3.0, +4.1, +8.4, and +6.9 m. p. s., respectively.

At Medford, Oreg., near the Pacific coast, the monthly resultants at the 0.5, 1, 2.5, and 3 km levels were oriented from 52° to 126° clockwise with respect to normal. At the 1.5 km level the direction was normal, while at the 2 km level it was oriented about 45° counterclockwise. The resultant velocities were slightly below normal. Conditions were accordingly such as to produce by these changes in direction a greater than normal transport of air from off the Pacific Ocean in the Northwestern States. At San Diego and Oakland, the resultant winds did not in general depart much from the normal directions and velocities, except at the 3 km level over the latter place where a departure of +3.2 m. p. s. occurred in the velocity.

The distributions of meteorological elements presented by the tabular data discussed above are of course the consequences of the passages of divers air masses and their interactions. It is therefore of interest to consider the "air mass history" of the month and to relate it to the observed mean distribution of the precipitation, temperature, humidity, etc. For somewhat over half of the month under review the trend of meteorological events to a considerable degree may be regarded as representing a persistence of the trends which were so strongly in evidence during the preceding month (see the November summary of *Aerological Observations*). Thus a number of offshoots of the well-developed north Pacific HIGH crossed over our Pacific coast and brought with them P_P air masses which contributed in a large measure to the conditions that later prevailed to the east. The high pressure systems which arose in this way over the middle Pacific coast region produced an accentuated transport of moist air from the ocean into the Northwestern States (note above discussion regarding resultant winds in that region). The frontal surfaces of the P_C air masses which frequently moved down over our northern border afforded a means whereby this moist air could be elevated with the consequent production of abnormally high precipitation in northern Idaho and Montana (200 percent of normal near Havre—see *Weekly Weather and Crop Bulletin*, January 13, 1937, and inset map on chart V of this REVIEW). The P_P HIGHS, reinforced to some extent by the P_C air masses just referred to, produced deficient precipitation and subnormal free-air temperatures in other parts of the northwest, the middle and the north Pacific coasts, and the eastern plateau region.

In the Pacific Southwest and adjacent plateau region a number of LOWS formed as waves in the southern peripheries of the P_P HIGHS and moved eastward, thus causing somewhat supernormal precipitation in that area when N_{PP} and T_P air masses overrode the denser P_P air.

The trajectory of the P_P and N_{PP} air masses along the eastern plateau region was attended by considerable subsidence, and superior dry air not infrequently made its appearance along the extremes of its southward movement in western Texas and the Gulf of Mexico. This doubtless contributed to the generally deficient precipitation along the Gulf coast.

The moist N_{PP} (and relatively warm P_P) air after passing over the plateau was frequently brought under the influence of the HIGHS of P_C origin which moved down over the north-central part of the country, and the trajectories of the former air masses were such as to carry them around the eastern peripheries of the P_P HIGHS and then northward and eastward around and across the peripheries of colder P_C and P_P HIGHS. The resultant ascent of the moist air in somewhat abnormal amount gave rise to above-normal precipitation in the Mississippi Valley.

The considerable southward movements of the P_C and P_P air masses and HIGHS prevented much warm, moist air from flowing up the Mississippi Valley, but the N_{PP} and T_M air masses reacting upon the southern frontal boundaries of these colder air masses produced waves therein with the consequent development of LOWS. These progressed eastward and then northward along the peripheries of the HIGHS so that the region near to and especially east of the Appalachian Mountain chain received an abundant supply of precipitation, particularly along the coast.

The conditions of deficient humidity and precipitation as well as of excessive temperatures, noted in the region south of the Great Lakes from St. Louis northeastward, were presumably connected with the subsidence which occurred in the N_{PP} air masses after the climax had been passed following the active stage of their role in the cyclones that were formed by the interactions thereof (and the relatively warmer P_P air masses) upon the colder P_C and P_P air masses.

TABLE 1.—*Mean free-air temperatures and relative humidities obtained by airplanes during December 1936*

TEMPERATURE (° C.)

Station	Altitude (meters) m. s. l.																		Number of observations
	Surface		500		1,000		1,500		2,000		2,500		3,000		4,000		5,000		
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	
Barksdale Field (Shreveport), La.[1] (52 m)	6.7		10.0		7.7		6.7		5.9		3.8		1.5		−3.4		−10.6		24
Billings, Mont.[2] (1089 m)	−3.5	−0.6					−1.0	−1.3	−2.5	−1.3	−5.1	−1.2	−8.4	−1.0	−14.9	−1.2	−21.7	−1.4	30
Boston, Mass.[1] (5 m)	1.0	+3.0	0.8	+3.4	−0.4	+3.4	−0.7	+4.0	−1.5	+4.4	−3.8	+4.0	−6.1	+4.0	−11.3	+3.7	−16.1	+4.6	21
Cheyenne, Wyo.[2] (1873 m)	−3.8	−0.2							−2.4	−0.6	−1.8	−0.2	−4.1	+0.3	−9.9	+0.4	−16.8	+0.3	31
El Paso, Tex.[2] (1194 m)	3.4						6.7		6.4		4.0		1.4		−4.0		−10.2		31
Fargo, N. Dak.[2] (274 m)	−11.2	+0.7	−9.0	+1.9	−7.7	+1.0	−7.1	0.0	−8.2	−0.4	−10.3	−0.6	−12.6	−0.7	−18.0	−0.7	−24.5	−0.9	27
Kelly Field (San Antonio), Tex.[1] (206 m)	7.0	−0.5	11.7	+0.8	10.7	+0.4	8.8	−0.4	7.2	−0.6	5.9	−0.2	3.4	−0.7	−3.5	−1.4	−10.8	−1.6	27
Lakehurst, N. J.[3] (39 m)	−0.4	+1.4	0.9	+2.6	0.5	+3.9	0.6	+4.9	−0.4	+5.1	−2.6	+5.3	−4.5	+5.5	−9.9	+5.2			19
Maxwell Field (Montgomery), Ala.[1] (52 m)	7.9	+3.4	9.5	+3.0	8.8	+2.7	7.8	+2.2	6.3	+1.7	4.4	+1.4	2.3	+1.4	−3.0	+1.8	−9.1	+1.3	19
Miami, Fla.[2] (4 m)	18.1		18.9		15.5		12.8		10.9		9.1		6.9		1.7		−5.0		31
Mitchel Field (Hempstead, L. I.), N. Y.[1] (29 m)	0.2	+2.2	1.5	+4.4	1.0	+5.3	1.2	+6.4	−0.4	+6.1	−2.0	+6.6	−3.9	+6.9	−10.1	+6.0			18
Murfreesboro, Tenn.[2] (174 m)	2.9	+1.3	5.1	+2.1	5.3	+2.9	4.1	+2.5	2.5	+2.0	0.4	+1.9	−2.0	+1.7	−7.1	+1.2	−12.7	+1.7	30
Norfolk, Va.[3] (10 m)	3.7	−0.5	4.4	+0.6	3.8	+1.4	2.9	+1.6	1.6	+1.5	−0.4	+1.4	−2.8	+0.9	−8.2	+0.7	−14.5	+0.1	14
Oakland, Calif.[2] (2 m)	6.9		9.5		7.9		6.1		3.8		1.4		−1.4		−7.9		−15.0		31
Oklahoma City, Okla.[2] (391 m)	4.0	+1.7	4.9	+1.3	7.2	+1.7	6.1	+1.6	4.4	+1.7	2.3	+1.8	−0.4	+1.7	−5.8	+1.6	−13.0	+1.4	31
Omaha, Nebr.[2] (300 m)	−3.0	+1.2	−1.9	+1.5	−0.1	+1.6	0.5	+1.2	−1.4	+0.5	−4.1	0.0	−6.9	−0.4	−13.1	−0.7	−19.8	−1.0	31
Pearl Harbor, Territory of Hawaii[3] (6 m)																			
Pensacola, Fla.[3] (13 m)	10.2	+0.7	11.7	+1.6	11.3	+1.6	9.5	+1.0	7.9	+0.8	5.5	+0.4	4.0	+1.0	−1.4	+0.6	−7.3	+0.5	28
Salt Lake City, Utah[2] (1288 m)	0.9						2.4		1.9		−0.7		−3.5		−8.4		−14.1		31
San Diego, Calif.[3] (10 m)	10.0	−1.7	13.1	0.0	11.0	−1.1	8.5	−1.3	5.9	−1.6	3.4	−1.6	0.7	−1.7	−5.5	−1.9	−12.1	−2.3	30
Sault Ste. Marie, Mich.[2] (221 m)	−5.3		−5.2		−6.0		−6.1		−7.3		−8.7		−11.2		−17.0		−23.7		28
Scott Field (Belleville), Ill.[1] (135 m)	−2.4	+1.1	1.8	+3.0	3.5	+3.8	2.4	+3.3	0.9	+3.0	−1.4	+2.7	−3.2	+2.5	−8.4	+2.2	−14.9	+1.4	20
Seattle, Wash.[3] (10 m)	4.7		1.6		−1.0		−3.7		−7.2		−10.2		−12.6		−18.9				9
Selfridge Field (Mount Clemens), Mich.[1] (177 m)	−2.5		−0.2		−0.7		−0.6		−1.9		−3.9		−6.4		−11.0		−16.6		27
Spokane, Wash.[2] (596 m)	0.7	+0.5			0.8	+0.1	−0.3	−0.8	−3.0	−2.2	−6.1	−3.0	−9.4	−3.5	−15.4	−3.4	−21.0	−2.5	31
Washington, D. C.[3] (13 m)	1.2	−0.2	2.8	+1.2	1.7	+1.3	1.4	+2.1	1.1	+2.8	−1.3	+2.5	−3.7	+1.7	−8.7	+1.3	−14.6	+0.9	24
Wright Field (Dayton), Ohio[1] (244 m)	−1.7	+2.0	−0.4	+2.8	0.9	+3.9	1.1	+4.7	−0.6	+4.3	−2.9	+3.9	−5.3	+3.5	−10.6	+2.8	−16.4	+2.7	20

RELATIVE HUMIDITY (PERCENT)

Station	Surface Mean	Surface Departure	500 Mean	500 Departure	1,000 Mean	1,000 Departure	1,500 Mean	1,500 Departure	2,000 Mean	2,000 Departure	2,500 Mean	2,500 Departure	3,000 Mean	3,000 Departure	4,000 Mean	4,000 Departure	5,000 Mean	5,000 Departure	Number of observations
Barksdale Field (Shreveport), La.	84		64		64		57		49		46		44		38		35		
Billings, Mont.	67	0					60	+3	59	+4	61	+5	64	+5	63	+5	63	+8	
Boston, Mass.	74	+3	71	+2	69	+2	59	−3	48	−8	45	−9	46	−7	41	−10	42	−6	
Cheyenne, Wyo.	63	0							61	+1	55	+1	54	0	52	+1	51	+2	
El Paso, Tex.	70						52		46		45		41		32		30		
Fargo, N. Dak.	77	−6	69	−11	64	−8	61	−2	54	−3	52	−2	51	0	48	−1	48	+1	
Kelly Field (San Antonio), Tex.	88	+1	67	−1	56	−2	52	0	52	+4	42	−1	37	−1	35	+1	32	+1	
Lakehurst, N. J.	74	−2	64	−7	59	−10	45	−17	39	−18	42	−14	36	−16	36	−12			
Maxwell Field (Montgomery), Ala.	78	0	64	0	60	+3	47	+1	40	+1	37	+1	33	−1	29	−3	25	−5	
Miami, Fla.	88		77		79		69		63		55		47		35		31		
Mitchel Field (Hempstead, L. I.), N. Y.	78	0	71	−2	66	−4	55	−8	45	−12	38	−16	33	−17	34	−11			
Murfreesboro, Tenn.	90	+6	75	+1	58	−8	56	−2	51	0	50	+1	48	+3	40	−1	39	−2	
Norfolk, Va.	77	+6	63	+1	51	−6	46	−5	41	−4	38	−5	36	−5	32	−4	31	0	
Oakland, Calif.	80		68		66		57		51		50		48		42		40		
Oklahoma City, Okla.	85	+4	79	+4	62	+1	58	+3	49	+1	43	−1	40	−1	40	+2	39	+3	
Omaha, Nebr.	91	+6	82	+3	69	+3	58	+4	53	+4	50	+4	50	+5	47	+3	48	+6	
Pearl Harbor, Territory of Hawaii																			
Pensacola, Fla.	86	+3	80	+6	66	+2	59	+2	52	+1	48	0	41	−4	35	−2	31	−5	
Salt Lake City, Utah	81						71		64		65		66		57		55		
San Diego, Calif.	79	+6	65	+4	59	+8	54	+8	49	+8	45	+9	43	+11	39	+10	37	+11	
Sault Ste. Marie, Mich.	85		89		84		68		57		53		55		58		55		
Scott Field (Belleville), Ill.	80	−2	63	−6	47	−13	45	−9	44	−5	46	−1	46	+3	45	+2	42	+1	
Seattle, Wash.	85		89		87		87		82		82		80		78				
Selfridge Field (Mount Clemens), Mich.	85		80		75		58		53		45		47		46		50		
Spokane, Wash.	85	−1			86	0	80	+5	79	+10	78	+11	77	+12	70	+11	63	+7	
Washington, D. C.	74	+2	56	−8	54	−6	50	−7	43	−9	42	−6	37	−8	33	−10	32	−8	
Wright Field (Dayton), Ohio	83	+1	75	−3	58	−11	42	−16	38	−13	37	−10	34	−10	29	−12	32	−10	

Observations taken about 4:00 a. m., 75th meridian time, except along the Pacific coast and Hawaii where they are taken at dawn.

[1] Army. [2] Weather Bureau. [3] Navy.

NOTE.—The departures are based on normals covering the following total number of observations made during the same month in previous years, including the current month (years of record are given in parentheses following the number of observations): Billings, 92 (3); Boston, 104 (5); Cheyenne, 93 (3); Fargo, 88 (3); Kelly Field, 77 (3); Lakehurst, 71 (3); Maxwell Field, 70 (3); Mitchel Field, 70 (3); Murfreesboro, 82 (3); Norfolk, 115 (7); Oklahoma City, 87 (3); Omaha, 177 (6); Pensacola, 173 (9); San Diego, 189 (8); Scott Field, 57 (3); Seattle, 40 (7); Spokane, 85 (3); Washington, 188 (12); Wright Field, 65 (3).

TABLE 1.—*Mean free-air temperatures and relative humidities obtained by airplanes during December 1936*—Continued

LATE REPORT FOR NOVEMBER 1936

TEMPERATURE (° C.)

Station	Surface		500		1,000		1,500		2,000		2,500		3,000		4,000		5,000		Number of observations
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	
Pearl Harbor, Territory of Hawaii[1] (6 m.)	21.9	−2.2	20.7	−0.8	16.8	−0.9	14.1	−0.8	13.1	+0.1	12.2	+0.8	9.9	+0.8	3.0	0.0	−5.4	−3.4	30

RELATIVE HUMIDITY (PERCENT)

Station	Surface		500		1,000		1,500		2,000		2,500		3,000		4,000		5,000		
Pearl Harbor, Territory of Hawaii	80	+5	75	0	80	+1	76	+1	60	−5	39	−12	29	−12	21	−10	11	−16	------

LATE REPORT FOR OCTOBER 1936

TEMPERATURE (° C.)

Station	Surface		500		1,000		1,500		2,000		2,500		3,000		4,000		5,000		
Coco Solo, C. Z.[1]	25.7	------	23.2	------	20.7	------	18.4	------	16.1	------	13.9	------	11.7	------	6.6	------	1.9	------	30

RELATIVE HUMIDITY (PERCENT)

Station	Surface		500		1,000		1,500		2,000		2,500		3,000		4,000		5,000		
Coco Solo, C. Z.	89	------	87	------	87	------	85	------	84	------	80	------	79	------	80	------	75	------	------

Observations taken about 4:00 a. m., 75th meridian time, except along the Pacific coast and Hawaii where they are taken at dawn.

[1] Navy.

NOTE.—The departures are based on normals covering the following total number of observations made during the same month in previous years, including the current month (years of record are given in parenthesis following the number of observations): Pearl Harbor, 144 (8).

TABLE 2.—*Free-air resultant winds (meters per second) based on pilot-balloon observations made near 5 a. m. (E. S. T.) during December 1936*

[Wind from N=360°, E=90°, etc.]

Altitude (m) m. s. l.	Albuquerque, N. Mex. (1,554 m)		Atlanta, Ga. (309 m)		Billings, Mont. (1,088 m)		Boston, Mass. (15 m)		Cheyenne, Wyo. (1,873 m)		Chicago, Ill. (192 m)		Cincinnati, Ohio (153 m)		Detroit, Mich. (204 m)		Fargo, N. Dak. (274 m)		Houston, Tex. (21 m)		Key West, Fla. (11 m)		Medford, Oreg. (410 m)		Murfreesboro, Tenn. (180 m)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°		°	
Surface	327	1.4	347	1.7	259	3.6	306	2.5	263	3.3	236	1.7	313	0.4	235	2.4	270	1.4	42	1.4	47	2.4	221	0.2	178	0.4
500	-----	-----	68	3.1	-----	-----	316	5.2	-----	-----	246	4.8	231	4.0	248	5.8	270	3.9	95	2.5	89	5.1	198	0.5	169	2.5
1,000	-----	-----	79	1.9	-----	-----	300	7.1	-----	-----	258	8.4	244	6.5	252	7.3	273	5.5	291	1.2	107	4.2	235	1.9	195	3.0
1,500	-----	-----	280	1.4	256	7.9	311	7.4	-----	-----	260	11.8	255	6.5	262	10.8	270	8.3	302	3.3	125	2.4	228	3.6	244	2.8
2,000	271	2.8	305	3.3	275	8.7	303	9.4	261	6.2	265	11.6	282	5.8	279	10.7	282	10.5	290	4.5	155	0.4	266	2.8	278	3.2
2,500	289	4.8	301	5.3	282	9.4	297	7.1	277	12.0	273	12.8	260	4.9	281	11.8	285	12.0	288	6.0	240	1.2	316	3.3	280	4.4
3,000	278	7.4	292	6.5	284	10.8	-----	-----	289	13.1	280	11.5	258	4.4	275	14.0	-----	-----	283	6.8	263	3.0	23	7.9	267	5.1
4,000	265	12.3	266	5.4	285	10.7	-----	-----	285	10.9	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	227	5.6	-----	-----	267	5.5
5,000	283	9.2	-----	-----	-----	-----	-----	-----	273	10.7	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

Altitude (m) m. s. l.	Newark, N. J. (14 m)		Oakland, Calif. (8 m)		Oklahoma City, Okla. (402 m)		Omaha, Nebr. (306 m)		Pearl Harbor, Territory of Hawaii[1] (68 m)		Pensacola, Fla.[1] (24 m)		St. Louis, Mo. (170 m)		Salt Lake City, Utah (1,294 m)		San Diego, Calif. (15 m)		Sault Ste. Marie, Mich. (198 m)		Seattle, Wash. (14 m)		Spokane, Wash. (603 m)		Washington, D. C. (10 m)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°		°	
Surface	318	2.1	68	1.4	185	1.9	77	0.2	-----	-----	29	4.0	180	0.5	157	3.3	27	0.7	157	0.9	179	1.7	221	1.0	343	1.6
500	300	4.7	26	1.1	190	5.5	225	2.3	-----	-----	79	5.2	233	4.0	-----	-----	52	0.4	230	4.0	190	2.0	-----	-----	329	3.5
1,000	289	9.4	354	2.4	231	8.4	255	5.1	-----	-----	169	1.4	242	6.6	-----	-----	111	0.4	235	6.6	175	2.3	195	4.6	298	4.0
1,500	283	10.0	332	1.5	249	6.6	266	6.1	-----	-----	360	0.6	261	7.3	170	4.3	325	0.7	-----	-----	196	5.8	227	9.1	304	7.8
2,000	289	10.9	339	1.1	266	5.6	274	8.2	-----	-----	238	1.7	267	7.9	192	5.5	336	2.4	-----	-----	229	5.9	258	8.8	297	8.8
2,500	301	12.0	299	3.9	246	5.8	273	9.3	-----	-----	258	1.4	265	7.9	230	4.4	298	3.1	-----	-----	-----	-----	240	11.8	291	7.6
3,000	292	9.6	319	6.9	271	7.2	275	9.3	-----	-----	313	3.4	271	8.4	265	6.5	301	4.6	-----	-----	-----	-----	239	15.8	292	9.5
4,000	-----	-----	-----	-----	267	8.4	-----	-----	-----	-----	261	8.6	291	7.2	270	9.3	314	6.4	-----	-----	-----	-----	261	14.2	-----	-----
5,000	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

[1] Navy stations.

AEROLOGICAL OBSERVATIONS FOR THE YEAR 1936

[Aerological Division, D. M. LITTLE in charge]

By L. P. HARRISON

Table 1 presents the mean free-air temperatures and relative humidities obtained by airplanes during the year 1936. Departures from normal are given for five stations where the length of record is 4 or more years (see footnote to table).

The data are too meagre to warrant much discussion. In comparing the values for the various stations, it is necessary to keep in mind that only 99 airplane observations were made at Seattle, Wash., during the year, so that the means for that place have much less weight than the means for the remaining stations. It is of interest to construct isothermal and isohygrometric charts for the standard levels. The apparent anomalous coldness of the free air over San Antonio (Kelly Field), Tex., with respect to surrounding places is noteworthy. Similarly, attention should be directed to the relative dryness of the free air over Montgomery (Maxwell Field), Ala.

A general statement regarding the aerological activities of the Weather Bureau during 1936 follows: At the end of the year the Weather Bureau had 12 regular airplane weather observation stations in continental United States where flights were made by private operators under contract. Flights were made by the War Department at eight stations in cooperation with the Weather Bureau, while flights were made by the Navy Department at nine stations. During August and September 1936 the Weather Bureau established new airplane stations at Miami, Fla., Oakland, Calif., Salt Lake City, Utah, and Sault Ste. Marie, Mich. On September 15, 1936, the Weather Bureau established a special airplane weather observation station at Fairbanks, Alaska, to operate until March 15, 1937, with funds provided in a special grant authorized under the Bankhead-Jones Act, for the investigation of the structure of Polar Continental air and the development of cold waves in North America. The Navy Department began making regular airplane observations at Coco Solo, Canal Zone, and St. Thomas Island, Virgin Islands, during the latter part of the year.

The total number of pilot balloon stations maintained by the Weather Bureau during the year was 77, where 247 observations were made daily over the country as a whole.

During the International Month of November, the Weather Bureau released 37 sounding balloons at Omaha, Nebr. Thus far 28 of the meteorographs so released (76 percent) have been returned.

During the last half of that month at the same place, 11 radiometeorographs with sounding balloon meteorographs attached were also released. Thus far nine of these have been found. The radiometeorographs were of the type designed by L. F. Curtiss and A. V. Astin, of the National Bureau of Standards, in cooperation with the Weather Bureau.

In addition, six sounding balloons with meteorographs and attached devices for capturing air samples at great heights were released for F. A. Paneth, of the Imperial College of Science and Technology, London. Five of these have already been returned.

The Aeronautical Engineering Department of the Institute of Technology at the University of Minnesota under the direction of John D. Akerman released a small number of sounding-balloon meteorographs for the Weather Bureau near Minneapolis, Minn., during the latter part of November and early December.

A number of experimental radiometeorograph soundings were made at Washington, D. C., during the course of the year by L. F. Curtiss, of the National Bureau of Standards, in cooperation with the Weather Bureau. Progress is still being made in the development of a radiometeorograph which can be successfully used for daily ascents.

TABLE 1.—*Mean free-air temperatures and relative humidities obtained by airplanes during year 1936*

TEMPERATURE (°C.)

Stations	Altitude (meters) m. s. l.																		Number of observations
	Surface		500		1,000		1,500		2,000		2,500		3,000		4,000		5,000		
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	
Barksdale Field (Shreveport), La.[1] (52 m)	14.6	......	16.8	......	15.0	......	12.9	......	10.6	......	8.2	......	5.7	......	0.1	......	−6.6	......	336
Billings, Mont.[2] (1089 m)	5.2	......	......	......	......	......	7.5	......	5.5	......	2.5	......	−0.8	......	−7.4	......	−14.3	......	360
Boston, Mass.[1] (5 m)	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Cheyenne, Wyo.[2] (1873 m)	3.8	......	......	......	......	......	......	......	5.2	......	5.0	......	2.1	......	−4.9	......	−12.4	......	361
El Paso, Tex.[2] (1194 m)	13.7	......	......	......	......	......	15.4	......	13.4	......	10.2	......	6.9	......	0.0	......	−6.8	......	366
Fargo, N. Dak.[2] (274 m)	0.6	......	3.1	......	2.7	......	1.7	......	0.0	......	−2.3	......	−5.0	......	−10.7	......	−17.1	......	349
Kelly Field (San Antonio), Tex.[1] (206 m)	14.6	......	12.3	......	11.5	......	9.8	......	7.9	......	5.6	......	2.8	......	−3.5	......	−10.4	......	325
Lakehurst, N. J.[3] (39 m)	8.3	......	8.7	......	7.1	......	5.5	......	3.6	......	1.6	......	−0.6	......	−6.1	......	−11.9	......	280
Maxwell Field (Montgomery), Ala.[1] (52 m)	15.5	......	16.7	......	14.8	......	12.3	......	10.1	......	7.8	......	5.3	......	−0.5	......	−6.5	......	308
Mitchel Field (Hempstead, L. I.), N. Y.[1] (29 m)	7.9	......	8.5	......	7.1	......	5.4	......	3.4	......	1.4	......	−0.9	......	−6.1	......	−12.2	......	277
Murfreesboro, Tenn.[2] (174 m)	11.3	......	13.3	......	12.1	......	10.1	......	7.8	......	5.4	......	2.9	......	−2.7	......	−8.7	......	357
Norfolk, Va.[3] (10 m)	12.7	−1.1	13.2	−0.1	10.9	−0.4	8.7	−0.4	6.5	−0.3	4.1	−0.4	1.6	−0.5	−4.1	−0.9	−10.0	−1.0	228
Oklahoma City, Okla.[2] (391 m)	12.5	......	13.9	......	14.2	......	12.6	......	10.3	......	7.5	......	4.4	......	−2.0	......	−8.4	......	349
Omaha, Nebr.[2] (300 m)	6.8	−0.6	8.4	−0.2	9.2	−0.4	8.2	−0.3	6.2	−0.3	3.5	−0.4	0.6	−0.4	−5.8	−0.4	−12.8	−0.7	362
Pearl Harbor, Territory of Hawaii[3] (6 m)	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Pensacola, Fla.[3] (13 m)	16.8	−0.8	17.4	+0.3	15.4	+0.3	13.1	+0.2	10.8	+0.2	8.4	+0.2	6.0	+0.3	0.4	+0.3	−5.6	+0.3	345

[1] Army. [2] Weather Bureau. [3] Navy.

TABLE 1.—*Mean free-air temperatures and relative humidities obtained by airplanes during year 1936*—Continued

TEMPERATURE (°C.)

Stations	Altitude (meters) m. s. l.																		Number of observations
	Surface		500		1,000		1,500		2,000		2,500		3,000		4,000		5,000		
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	
San Diego, Calif.[3] (10 m)	14.8	−1.3	15.2	+0.1	16.1	+0.5	14.9	+0.6	12.3	−0.1	9.6	−0.2	6.6	−0.4	0.6	−0.2	−6.0	−0.2	357
Scott Field (Belleville), Ill.[1] (135 m)	7.9		11.1		10.9		9.2		6.8		4.2		1.6		−4.4		−10.7		291
Seattle, Wash.[2] (10 m)	9.7	−1.3	7.6	−1.5	6.0	−1.2	3.7	−1.2	1.4	−1.0	−1.1	−1.0	−3.5	−0.9	−9.6	−1.4	−16.8	−2.2	99
Selfridge Field (Mount Clemens), Mich.[1] (177 m)																			
Spokane, Wash.[2] (596 m)	5.4				8.6		7.9		5.5		2.5		−0.6		−7.0		−13.7		362
Sunnyvale, Calif.[3] (10 m)																			
Washington, D. C.[3] (13 m)	9.6	−1.9	10.5	−0.3	8.6	−0.4	6.6	−0.4	4.6	−0.4	2.4	−0.4	0.0	−0.6	−5.2	−0.7	−10.6	−0.5	
Wright Field (Dayton), Ohio[1] (244 m)	7.4		9.2		8.5		6.9		4.8		2.4		−0.2		−5.7		−12.0		307

RELATIVE HUMIDITY (PERCENT)

Stations	Surface Mean	Surface Departure	500 Mean	500 Departure	1,000 Mean	1,000 Departure	1,500 Mean	1,500 Departure	2,000 Mean	2,000 Departure	2,500 Mean	2,500 Departure	3,000 Mean	3,000 Departure	4,000 Mean	4,000 Departure	5,000 Mean	5,000 Departure	Number of observations
Barksdale Field (Shreveport), La.	80		63		59		56		52		47		45		43		39		
Billings, Mont.	58						50		49		52		55		57		56		
Boston, Mass.																			
Cheyenne, Wyo.	66								61		53		52		53		54		
El Paso, Tex.	51						47		47		48		48		49		46		
Fargo, N. Dak.	75		65		60		56		53		51		51		50		50		
Kelly Field (San Antonio), Tex.	87		76		68		62		56		51		47		44		42		
Lakehurst, N. J.	79		66		62		59		57		54		50		46		42		
Maxwell Field (Montgomery), Ala.	78		62		58		57		50		46		42		38		34		
Mitchel Field (Hempstead, L. I.), N. Y.	82		73		69		67		63		58		54		51		49		
Murfreesboro, Tenn.	82		69		65		62		59		54		51		46		42		
Norfolk, Va.	80	+5	65	−1	61	−1	59	0	56	0	52	−1	49	0	47	+3	45	+5	
Oklahoma City, Okla.	69		65		56		53		50		48		47		46		43		
Omaha, Nebr.	74	−5	66	−6	58	−2	54	−1	52	0	52	+1	51	0	50	+1	50	+3	
Pearl Harbor, Territory of Hawaii																			
Pensacola, Fla.	86	+4	74	0	69	0	64	0	58	−1	53	−2	49	−2	43	−2	38	−3	
San Diego, Calif.	84	+9	76	+5	56	+3	44	+1	40	+4	37	+4	36	+5	35	+6	34	+7	
Scott Field (Belleville), Ill.	79		61		54		52		52		50		48		45		43		
Seattle, Wash.	79	+2	76	+2	71	+1	69	+3	65	+3	61	+4	57	+5	54	+6	52	+5	
Selfridge Field (Mount Clemens), Mich.																			
Spokane, Wash.	76				64		58		58		58		58		56		53		
Sunnyvale, Calif.																			
Washington, D. C.	79	+6	58	−6	57	−4	56	−3	55	−2	51	−3	48	−2	44	−2	41	−1	
Wright Field (Dayton), Ohio	81		71		65		60		58		56		53		50		49		

Observations taken about 4:00 a. m., 75th Meridian time except along the Pacific coast and Hawaii where they are taken at dawn.

[1] Army. [2] Weather Bureau. [3] Navy.

NOTE.—The departures are based on normals covering the following total number of observations made during the same month in previous years, including the current month: The departures are based on normals covering the following total number of observations made during previous years, including the current year. The figures in parentheses indicate the number of years of record. (When the number of years of record varies for the different months of the year, the various numbers pertinent thereto are all given): Norfolk, 1701 (6, 7, 8); Omaha, 1907 (5, 6); Pensacola, 2212 (8, 9); San Diego, 2201 (8); Seattle, 693 (4, 6, 7).

RIVERS AND FLOODS

[River and Flood Division, W. J. MOXOM, temporarily in charge]

By BENNETT SWENSON

There was abundant precipitation during the month of December. The amounts were near normal to considerably above normal, rather generally, east of the Great Plains and also over a large area of the far Southwest; falls were scanty over most of the Northwest and the Rio Grande Valley.

Over the Atlantic slope drainage, where the precipitation was generally quite heavy, the rivers from southern Virginia to Florida were near or above flood stage at some time or other during the month. The most severe flooding occurred in the Neuse and Cape Fear Rivers in North Carolina and in the Santee and Savannah Rivers in South Carolina and Georgia. These rivers were in flood a good part of the month, however, no appreciable amount of damage was incurred.

Some flooding occurred in the Sulphur River in Texas during the first half of the month and again at the close. The lower Ohio River and tributaries began to rise during the closing days of the month from the gradual accumulation of precipitation. The Wabash River system reached flood stage in the West Fork of the White on the 31st and in the Wabash proper on January 1st and 2d. The Tennessee and Cumberland Rivers showed rises with the Tennessee going just slightly above flood stage at Decatur, Ala., on the 27th.

At St. Louis, Mo., on the Mississippi River, a low stage of 3.2 feet below zero was recorded on the 17th which is the lowest free-water stage of record for the month of December at that station.

Table of flood stages during December 1936

[All dates in December unless otherwise specified]

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC SLOPE DRAINAGE	*Feet*			*Feet*	
James: Columbia, Va	10	9	9	11.1	9
Tar: Greenville, N. C	13	17	21	13.7	20
Little: Kenly, N. C	8	14	19	12.2	18
Neuse:					
Neuse, N. C	14	11	13	15.9	12
Smithfield, N. C	13	12	20	18.4	14
Goldsboro, N. C	13	12	26	20.9	19
Kinston, N. C	14	16	28	17.9	22
Cape Fear: Lock No. 2, Elizabethtown, N. C	20	11	21	27.0	13
Peedee:					
Mars Bluff Bridge, S. C	17	18	24	18.6	21
Poston, S. C	18	24	25	18.0	24–25
Saluda:					
Pelzer, S. C	6	20	20	6.5	20
Chappells, S. C	15	20	21	16.4	21
Santee:					
Rimini, S. C	12	3	6	13.0	5
		9	14	12.8	11
		17	26	13.5	24
		31	(1)	12.2	31
Ferguson, S. C	12	4	7	12.4	6, 7
		10	15	12.5	13
		17	28	13.0	21–23, 26
Savannah:					
Ellenton, S. C	14	9	12	16.3	10
		18	27	20.5	23
Clyo, Ga	13	28	(1)	14.6	30

[1] Continued into January.

Table of flood stages during December 1936—Continued

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
EAST GULF OF MEXICO DRAINAGE	*Feet*			*Feet*	
Apalachicola: Blountstown, Fla	15	22	27	17.4	24
MISSISSIPPI SYSTEM					
Ohio Basin					
West Fork of White: Anderson, Ind	8	31	(1)	8.7	31
Wabash: La Fayette, Ind	11	31	Jan. 3	15.2	Jan. 1, 2
New: New River, Tenn	18	7	7	20.4	7
French Broad: Asheville, N. C	6	31	Jan. 1	[2] 6.2	31
Tennessee:					
Hales Bar Lock, Tenn. (Upper gage)	44	8	9	44.1	8
Decatur, Ala	20	24	28	20.8	27
Arkansas Basin					
Poteau: Poteau, Okla	21	28	28	21.6	28
Petit Jean: Danville, Ark	20	6	10	22.5	8
		29	29	20.1	29
Red Basin					
Sulphur:					
Ringo Crossing, Tex	20	6	10	23.6	7
		27	31	22.3	28
Naples, Tex	22	12	16	24.0	14

[2] Estimated.

WEATHER ON THE ATLANTIC AND PACIFIC OCEANS

[The Marine Division, I. R. TANNEHILL in charge]

NORTH ATLANTIC OCEAN, DECEMBER 1936

By H. C. HUNTER

Atmospheric pressure.—Pressure averaged lower than normal over the north-central and the far northeastern portions of the North Atlantic. The pressure around southern Greenland was, in general, low from the 14th onward, while over the Iceland-British Isles region it was low from the 11th to the 20th. Pressure averaged slightly lower than normal in the area of the Greater Antilles and southern Florida. Elsewhere over the Atlantic high pressure was the rule, notably in the vicinity of the Maritime Provinces and Newfoundland. From Nova Scotia to Bermuda abnormally high pressure prevailed from the 19th to the end of December.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure (sea level) at selected stations for the North Atlantic Ocean and its shores, December 1936*

Station	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	29.39	−0.09	30.28	4	28.70	19
Reykjavik, Iceland	29.36	−.11	30.28	6	28.23	20
Lerwick, Shetland Islands	29.53	−.19	30.33	26	28.32	14
Valencia, Ireland	30.01	+.07	30.68	23, 24	28.70	14
Lisbon, Portugal	30.30	+.19	30.56	6	30.00	11
Madeira	30.16	+.07	30.45	31	29.94	4, 26
Horta, Azores	30.26	+.12	30.56	8, 12	29.88	17
Belle Isle, Newfoundland	29.96	+.22	30.88	10	29.30	18
Halifax, Nova Scotia	30.23	+.28	30.88	9	29.52	21
Nantucket	30.22	+.17-	30.71	8	29.46	20
Hatteras	30.21	+.08	30.66	23	29.63	17
Bermuda	30.20	+.08	30.48	31	29.92	14, 18
Turks Island	30.01	−.02	30.08	5	29.92	12
Key West	30.07	−.01	30.26	23	29.91	2
New Orleans	30.15	+.02	30.47	23	29.79	2

NOTE.—All data based on a. m. observations only, with departures compiled from best available normals related to time of observation, except Hatteras, Key West, Nantucket, and New Orleans, which are 24-hour corrected means.

The extremes of pressure noted in the vessel reports at hand are [1] 30.86 and 28.44 inches. The higher reading was taken about 300 miles east of Cape Race on the American liner *Black Gull*, during the forenoon of the 10th; the lower was recorded on the American steamer *Scanstates*, at noon on the 19th, when near latitude 58° N., longitude 21° W. Readings slightly outside these limits were taken at certain of the shore stations whose figures appear in table 1, while a pressure of 28.11 is reported to have occurred at Thorshavn, Faroe Islands, on the 14th.

Cyclones and gales.—Fewer intense gales have been reported than for the average December, and the first 10 and final 10 days were less stormy, considering the whole North Atlantic, than the intervening period. Stormy conditions were, however, noted near the American coast from the 2d to 4th when a LOW that was centered in the Gulf of Mexico, near Tampa, during the forenoon of the 1st, with little strength, moved northeastward near the coast line reaching Newfoundland on the 4th with much increased energy. Some vessels met fresh to whole gales in connection with this storm, particularly on the 3d. (See chart IX.)

Almost all the gales of force greater than 9 were noted during the period from the 12th to 21st, and most of these were met to eastward of midocean. Stormy weather was persistent at this time near, and far to northward and westward of, the British Isles. Two vessels on the 14th encountered hurricane winds, the American S. S. *City of Joliet* when about 500 miles west-southwest of Valencia, Ireland, and the Belgian S. S. *Katanga* about 300 miles south-southeast of Valencia.

In waters near the American coast there were some reports of whole gales and many of fresh to strong gales

[1] The international radio exchange (Rugby bulletin) of Dec. 8 contains an observation from a ship (name not given) in 44.5° N., 18.2° W., at 0600 g. m. t. of that date, with a pressure of 1,046 millibars (30.89 inches).

during the 16th to 19th in connection with a LOW, which had displayed little strength on the 14th, when near Cuba, but intensified as it advanced northeastward, crossing Newfoundland on the 18th.

A moderately strong disturbance noted from the 4th to 11th in mid-Atlantic, near and to northward of the Tropic of Cancer, is described on p. 428.

A norther of force 8 was experienced to southward of the center of the Gulf of Mexico, by the British motorship *San Alvaro*, during the 14th, while on the 25th and 26th intensified trades were noted by the British motorship *Greystoke Castle*, then about 700 miles northeast of Puerto Rico.

Fog.—There was less fog than during November 1936 over practically all areas to east and north of Cape Cod, including the waters adjacent to Europe; but from Cape Cod southwestward to Texas, chiefly in the vicinity of the coast, there was an increase over November.

From near the coast of southeastern Texas to the northern limit of the middle Atlantic coast the amount of fog during the month was in excess of the average for December; the 5°-square, 35° to 40° N., 70° to 75° W., with 10 days of record, led all other North Atlantic Ocean squares in fog frequency. The period from the 10th to the 18th was especially foggy in this area.

The waters adjacent to New England, the Maritime Provinces, and Newfoundland, also the northeastern part of the ocean, are indicated to have had somewhat less fog than usual for December.

OCEAN GALES AND STORMS, DECEMBER 1936

Vessel	Voyage		Position at time of lowest barometer		Gale began December	Time of lowest barometer December	Gale ended December	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Direction and highest force of wind	Shifts of wind near time of lowest barometer
	From	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				Inches					
Burgerdijk, Du. S. S.	Rotterdam	Halifax	50 43 N.	23 20 W.	3	5a, 3	4	29.80	SSW	SSW, 5	WNW	WNW, 9	SSW-WNW.
Exminster, Am. S. S.	Bone	New York	36 25 N.	66 37 W.	3	1p, 3	3	29.90	SSE	SW, 9	W	WSW, 9	SW-W.
American Trader, Am. S. S.	Halifax	London	42 18 N.	59 42 W.	2	6p, 3	3	29.59	ESE	S, 10	W	S, 10	SE-SW.
Tennessee, Dan. S. S.	New York	Oslo	[2]58 20 N.	7 11 W.	3	11p, 3	4	28.76	SW	SW, 10	NW	WNW, 11	SSW-WNW.
Myrtlebank, Br. M. S.	Gibraltar	Halifax	[2]37 12 N.	46 18 W.	6	1p, 6	7	29.66	N	N, 8	N	N, 9	S-NW-N.
Clara, Ital. S. S.	do	New York	32 59 N.	33 58 W.	6	4p, 6	6	29.41	SSE	S, 9	SSW	S, 10	SSE-SSW.
Charles L. D., Fr. M. S.	Buenos Aires	St. John, N. B.	27 20 N.	51 30 W.	6	Mdt, 7	10	29.50	NW	N, 4	NE	NW, 9	NW-NE.
San Blas, Pan. S. S.	Galveston	Santa Marta	11 36 N.	75 00 W.	6	4a, 8	10	29.71	E	NE, 7	E	NE, 7	None.
Antinous, Am. S. S.	Rotterdam	Corner Brook	49 50 N.	35 30 W.	11	4a, 13	13	29.49	WNW	W, 10	NNW	NW, 10	WSW-WNW.
Leerdam, Du. S. S.	Philadelphia	Rotterdam	49 17 N.	21 31 W.	12	4p, 13	13	29.06	SW	SW, 10	NW	SW, 10	SW-NW.
City of Joliet, Am. S. S.	Galveston	Bremen	48 12 N.	24 55 W.	13	4a, 14	14	29.27	WSW	NW, 9	WNW	NNW, 12	W-NNW.
Pres. Harding, Am. S. S.	Southampton	New York	51 00 N.	12 20 W.	13	5a, 14	14	28.52	SSW	SW, 10	NNW	SW, 10	SW-WNW.
Katanga, Belg. S. S.	Banane	Antwerp	47 02 N.	6 44 W.	13	2p, 14	14	29.23	SW	SW, 12	W	SW, 12	SW-NW.
San Alvaro, Br. M. S.	Tampico	New York	[2]23 57 N.	87 56 W.	14	4p, 14	14	29.91	N	N, 6	N	N, 8	
Oakman, Am. S. S.	Bremen	New Orleans	52 20 N.	3 00 E.	13	8p, 14	15	29.30	SSW	SSW, 10	WSW	SSW, 11	Steady.
Antinous, Am. S. S.	Rotterdam	Corner Brook	49 00 N.	41 00 W.	14	8p, 14	15	29.10	S	SW, 8	NW	SSW, 10	SSW-WNW.
Veendam, Du. S. S.	New York	Rotterdam	48 59 N.	36 11 W.	14	Mdt, 14	15	29.05	S	S, 8	WNW	SSW, 10	S-NW.
Pres. Harding, Am. S. S.	Southampton	New York	49 41 N.	21 29 W.	15	9a, 15	16	28.99	SW	WSW, 9	W	W, 10	SW-W.
Black Tern, Am. S. S.	Antwerp	Baltimore	49 05 N.	12 09 W.	15	6p, 15	16	29.38	WSW	SW, 10	WNW	SW, 10	SW-W.
City of Hamburg, Am. S. S.	Norfolk	Havre	42 50 N.	48 21 W.	16	2p, 16	17	29.75	WNW	WNW, 8	NW	NW, 10	None.
Topa Topa, Am. S. S.	Tampa	Manchester	48 30 N.	31 00 W.	16	3p, 16	18	28.54	S	W, 8	W	W, 10	S-W.
Veendam, Du. S. S.	New York	Rotterdam	50 20 N.	20 52 W.	16	10p, 16	17	28.78	S	SSW, 11	SW	SSW, 11	SSW-SW.
Scanstates, Am. S. S.	Copenhagen	Wilmington, Del.	58 38 N.	8 34 W.	17	Noon, 17	18	28.54	W	S, 8	W	W, 9	W-S-SW.
Yselhaven, Du. S. S.	Mobile	Bremen	39 01 N.	63 34 W.	16	2a, 18	19	29.40	SE	WSW, 8	NNW	S, 10	WSW-NNW.
Tampa, Am. S. S.	Gibraltar	New York	39 25 N.	67 13 W.	17	7a, 18	17	29.81	S	NNW, 6	NW	S, 10	
Pres. Harding, Am. S. S.	Southampton	do	45 45 N.	42 18 W.	18	6p, 18	18	28.99	SW	SSW, 10	W	SSW, 10	SSW-W.
Champlain, Fr. S. S.	Havre	do	49 53 N.	31 42 W.	18	3a, 19	20	28.80	W	SSW, 10	NW	S, 10	S-WSW.
Bremen, Ger. S. S.	New York	Cherbourg	47 27 N.	30 11 W.	18	10a, 19	19	29.27	S	SSW, 11	SW	SSW, 11	
Scanstates, Am. S. S.	Copenhagen	Wilmington, Del.	57 40 N.	21 02 W.	19	Noon, 19	20	28.44	SSE	SW, 9	W	SW, 11	SSE-SW.
Rotterdam, Du. S. S.	Rotterdam	New York	50 28 N.	31 01 W.	18	Noon, 19	20	28.88	WSW	SSW, 10	WNW	W, 11	SSW-NW.
City of Hamburg, Am. S. S.	Norfolk	Havre	48 47 N.	24 50 W.	18	1p, 19	20	29.55	SW	SSW, 10	SSW	SSW, 11	None.
Europa, Ger. S. S.	Cherbourg	New York	48 02 N.	22 22 W.	19	8p, 19	19	29.62	SSW	SSW, 9	W	SSW, 10	None.
R. G. Stewart, Am. S. S.	Port Arthur	do	[2]40 34 N.	74 00 W.	19	8a, 20	20	29.68	E	SSW, 6	SE	S, 9	SE-SSW.
Genral Gassouin, Fr. M. S.	New York	Antwerp	49 24 N.	15 06 W.	19	11a, 20	20	[3]29.88	SW	SSW, 8	S	SSW, 10	
Fluor Spar, Am. S. S.	Savannah	Liverpool	39 29 N.	62 15 W.	20	2a, 21	21	[3]29.60	SSE	SW, 9	NW	SSE, 10	SW-NW.
Emile Francqui, Belg. S. S.	Antwerp	New York	46 30 N.	42 10 W.	23	3a, 24	24	29.48	S	S, 9	W	S, 9	S-W.
Greystoke Castle, Br. M. S.	Belawan	do	25 55 N.	58 10 W.	25	10a, 25	26	29.84	NE	NE, 7	NE	NE, 8	E-NNE-NE.
Scanmail, Am. S. S.	Copenhagen	Portland, Me.	50 00 N.	46 40 W.	29	2p, 29	30	28.94	W	SW, 8	NW	NW, 9	SW-NW.
Jean Jadot, Belg. S. S.	Antwerp	New York	50 34 N.	31 53 W.	29	Mdt, 29	31	28.96	SW	SW, 9	NNW	SW, 10	SW-NW.
NORTH PACIFIC OCEAN													
Roseville, Nor. M. S.	Vancouver, B. C.	Singapore	46 30 N.	178 12 E.	[1]29	[1]Mdt, 30	1	29.01		WSW, 9		WSW, 9	
Corneville, Nor. M. S.	Hong Kong	Los Angeles	36 00 N.	154 54 E.	3	11p, 3	4	29.61	SSW	SSW, 9	SSW	SSW, 9	SSW-WSW.
Athelcrown, Br. M. S.	Nagasaki	do	37 23 N.	153 28 E.	3	4a, 4	4	29.58	ENE	NE, 8	NE	NE, 8	
Michigan, Am. S. S.	Masbate, P. I.	San Francisco	43 32 N.	152 50 W.	5	8a, 5	5	29.77	S	S, 8	W	SW, 10	S-SW.
Steel Age, Am. S. S.	Kahului, T. H.	Balboa	18 47 N.	125 18 W.	4	11a, 8	9	29.86	E	NE, 8	SE	NE, 8	
Empress of Russia, Br. S. S.	Yokohama	Victoria, B. C.	48 46 N.	178 53 E.	8	2a, 8	7	28.99	WSW	WSW, 8	SW	WSW, 9	ESE-WSW.
Athelcrown, Br. M. S.	Negasaki	Los Angeles	39 51 N.	177 26 E.	8	8p, 8	9	29.18	SE	SW, 8	W	W, 9	SE-SW-WSW.
Olympia, Am. S. S.	Legaspi, P. I.	do	34 24 N.	154 36 E.	8	6a, 8	8	29.98	WNW	WNW, 8	WNW	WNW, 10	
Hoyo Maru, Jap. M. S.	Estero	Yokohama	[2]34 55 N.	165 23 E.	8	1p, 8	8	29.65	W	W, 9	WNW	WNW, 9	W-WNW.
Heian Maru, Jap. M. S.	Yokohama	Vancouver	48 43 N.	176 27 E.	8	4p, 8	8	28.70	WSW	SW, 9	WNW	SW, 9	SW-WNW.
Golden Star, Am. S. S.	do	San Francisco	42 59 N.	167 48 E.	9	5p, 8	9	29.06	WNW	E, 6	W	WNW, 10	ESE-NE-WSW.
Silvermaple, Br. M. S.	Manila	do	47 18 N.	154 24 W.	8	2a, 9	9	29.55	SW	SW, 9	WSW	SW, 9	SW-WSW.
Olympia, Am. S. S.	Legaspi, P. I.	Los Angeles	36 48 N.	161 24 E.	9	11p, 9	10	29.94	W	W, 7	WNW	W, 9	
Golden Star, Am. S. S.	Yokohama	San Francisco	43 17 N.	177 30 W.	10	4p, 10	10	29.58	WNW	SW, 7	NNW	NW, 10	SW-NW.
Hoyo Maru, Jap. M. S.	Estero	Yokohama	[2]35 06 N.	147 08 E.	12	3p, 12	12	29.78	SSE	SW, 8	SW	S, 9	S-NW.
Pres. McKinley, Am. S. S.	Yokohama	San Francisco	46 20 N.	149 47 W.	13	Noon, 14	15	29.56	SW	W, 7	NW	W, 10	WSW-WNW.

[1] November.
[2] Position approximate.
[3] Barometer uncorrected.

OCEAN GALES AND STORMS, DECEMBER, 1936—Continued

Vessel	Voyage		Position at time of lowest barometer		Gale began December	Time of lowest barometer December	Gale ended December	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Direction and highest force of wind	Shifts of wind near time of lowest barometer
	From	To—	Latitude	Longitude									
NORTH PACIFIC OCEAN—Continued			° ′	° ′				*Inches*					
Chichibu Maru, Jap. M. S.	Honolulu	San Francisco	29 30 N.	145 36 W.	14	2p, 14	15	30.03	NNE	NNE, 8	NNE	NNE, 8	
Mayflower, Am. M. S.	Fishing grounds.	San Diego	13 51 N.	91 15 W.	14	6a, 14	15	29.89	NW	N, 2	N	N, 9	
Henderson, U. S. N.	Balboa	do	11 54 N.	90 18 W.	15	6p, 14	15	29.90	NE	ENE, 2	N	N, 8	ENE-NE.
H. M. Storey, Am. S. S.	do	Los Angeles	13 28 N.	91 03 W.	15	Noon, 14.	15	29.79	N	NW, 1	E	N, 9	
Golden Star, Am. S. S.	Yokohama	San Francisco	42 45 N.	147 50 W.	15	6a, 16	16	29.96	W	W, 8	W	W, 9	None.
Olympia, Am. S. S.	Legaspi, P. I.	Los Angeles	41 30 N.	148 47 W.	19	Noon, 19.	21	29.61	SSW	SW, 9	SW	SW, 11	S-W.
Texas, Am. S. S.	Yokohama	San Francisco	34 19 N.	139 58 E.	21	Noon, 21.	21	29.89		NE, 9	NE	NE, 9	
Heiyo Maru, Jap. M. S.	do	Honolulu	23 06 N.	161 21 W.	24	7p, 24	25	30.14	ENE	ENE, 7	ENE	ENE, 8	
Toorak, Br. S. S.	do	San Francisco	40 24 N.	130 44 W.	25	6a, 27	27	29.51	WNW	NNW, 6	N	NW, 9	None.
Otowasan Maru, Jap. M. S.	Tokuyama	Los Angeles	35 59 N.	155 07 E.	26	4p, 27	29	29.06	SE	WSW, 8	NW	SSE, 10	SE-S-W.
Golden Sun, Am. S. S.	Yokohama	San Francisco	[3]40 22 N.	165 33 E.	27	8a, 28	28	28.96	SSE	SW, 8	NW	S, 10	S-SW.
Empress of Japan, Br. S. S.	Honolulu	Victoria, B. C.	42 43 N.	134 59 W.	27	8a, 28	28	30.14	N	N, 7	N	NNW, 9.	
Montreal Maru, Jap. S. S.	Yokohama	Los Angeles	45 53 N.	174 10 W.	27	1a, 29	29	29.27	SE	SSE, 10	WSW	SE, 10	SSE-SW.
Texas, Am. S. S.	do	San Francisco	45 42 N.	170 10 E.	28	6p, 28	29	28.83	ESE	SSE, 10	WNW	SSE, 10	SE-SW.
Hoyo Maru, Jap. M. S.	do	Los Angeles	40 55 N.	178 50 E.	28	Noon, 29.	29	29.08	SSE	S, 9	NW	S, 10	S-WNW.
Texas, Am. S. S.	do	San Francisco	46 20 N.	179 00 W.	30	8p, 29	30	29.75	SSE	S, 10	S	S, 10	
Golden Sun, Am. S. S.	do	do	42 00 N.	176 40 E.	30	6p, 30	30	29.62	S	S, 9	S	S, 9	None.
Heiyo Maru, Jap. M. S.	Hilo	do	21 12 N.	153 18 W.	30	8a, 30	31	29.92	ENE	ENE, 6	ENE	ENE, 8	

[3] Position approximate.

NORTH PACIFIC OCEAN, DECEMBER 1936

By WILLIS E. HURD

Atmospheric pressure.—During December 1936, owing to the prevailing movement of cyclones in higher latitudes of the North Pacific, the average center of the Aleutian LOW lay over the Bering Sea, with the lowest recorded average pressure, 29.49 inches, at St. Paul. The lowest single barometer reading of the month was 28.44, reported by the British steamship *Empress of Russia* on the 21st, near 52° N., 147° W.

Anticyclonic conditions prevailed for the most part between approximately 20° and 40° N., except for a few days in east longitudes during which cyclones penetrated the high pressure region. Pressure departures along this belt were abnormally high, except on waters adjacent to the California coast as indicated by the average barometer at San Francisco, 30.06, which is 0.06 inch below the normal. The highest departure, +0.15, occurred at Midway Island. In the Far East the plus departures of 0.11 inch at Naha and of 0.09 at Chichishima attest to the prevalence of anticyclones from China as dominating the weather conditions in lower Japanese and eastern Chinese waters.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, North Pacific Ocean, December 1936, at selected stations*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow	29.84	−0.19	30.00	2	29.10	30
Dutch Harbor	29.59	+.03	30.24	25	28.74	9
St. Paul	29.49	−.00	30.06	25	28.74	9
Kodiak	29.58	+.02	30.40	29	28.68	9
Juneau	29.70	−.09	30.34	31	28.87	16
Tatoosh Island	29.94	−.02	30.59	10	29.42	26
San Francisco	30.06	−.06	30.43	17	29.56	30
Mazatlan	29.93	.00	30.04	20	29.86	8, 11, 30
Honolulu	30.04	+.03	30.22	15	29.84	4
Midway Island	30.16	+.15	30.40	17	29.88	25
Guam	29.84	−.03	29.92	7, 10, 11	29.56	15
Manila	29.84	−.02	29.94	11, 12	29.74	24
Hong Kong	30.06		30.17	13	29.97	16
Naha	30.09	+.11	30.30	15	29.74	4
Chichishima	30.09	+.09	30.36	15	29.71	26
Urakawa	30.00		30.59	15	29.68	31

NOTE.—Data based on 1 daily observation only, except those for Juneau, Tatoosh Island, San Francisco, and Honolulu, which are based on 2 observations. Departures are computed from best available normals related to time of observation.

Storminess and gales.—December was less violently stormy in 1936, according to ship reports, than the preceding month. In November there were 9 days on which gales of force 11 to 12, well scattered as to locality, occurred; in December there were only 2, one reported by the British Steamship *Irisbank*, near 52¼° N., 159° W. on the 12th; the other by the American Steamship *Olympia*, in 41°31′ N., 148°47′ W., on the 19th. There were, in addition, 9 days—the 5th, 8th to 10th, 14th, and 27th to 30th—with local gales of force 10, occurring principally along the northern routes between longitudes 155° E. and 145° W., as itemized in the accompanying table of gales.

Extratropical cyclones.—The majority of the December cyclones, as they appear on our North Pacific maps, were of purely oceanic nature. That is, they were largely the fluctuating disturbances, some of considerable depth, of the type peculiar to the Aleutian LOW. This month these cyclones had their centers mostly in high latitudes and, except on the western part of the ocean, affected the weather south of the fortieth parallel to only a minor degree.

Eastward from Yokohoma fresh to strong gales were experienced by ships near the coast on the 12th and 21st. Between 150° and 165° E., 34° and 38° N., gales of force 8 to 10 were reported on the 3d, 4th, 8th, 9th, and 27th. Of these dates, the 8th and 9th were more generally widespread in storminess than any others of the month as, in addition to the more southerly locality of storm occurrence, those dates were also locally stormy to the northward, northeastward as far as the Aleutian Islands, and eastward along the northern routes as far as longitude 155° W. On the 9th the island stations of St. Paul, Dutch Harbor, and Kodiak had their lowest barometer readings of the month as noted in table 1.

During the period 13th–18th storminess abated along the northern routes, although scattered gales were reported in middle longitudes on the 14th to 16th.

On the 19th–21st disturbed conditions intensified between the Gulf of Alaska and the fortieth parallel. In the southern part of the area on the 19th the Steamship *Olympia*, as previously mentioned, encountered a gale of storm force, one of the two heaviest gales of the month, but with lowest barometer only 29.61. On the 20th, between 45° and 51° N., 140° and 145° W., pressure had fallen to 28.76 inches, with fresh westerly gales

occurring. On the 21st with the lowest pressure of the month, 28.44 inches, reported by the British Steamship *Empress of Russia* near 52° N., 147° W., the highest wind force recorded for the stormy area was 8. The cyclone filled rapidly on the following day.

Stormy weather occurred on California coastal waters during the 26th to 28th. Ships reported strong gales on the 26th and 27th between 40°–43° N., 130°–135° W. Nearer the coast, press reports speak of the heaviest storm in years on the 27th along southern California during which several small vessels were grounded and damaged or sunk.

The final days of the month witnessed scattered gales over northern and western waters with reports of isolated winds of force as high as 10 on the 27th to 30th.

Gales of low latitudes.—On December 4 a tropical depression moved northward over the Hawaiian Islands. During its brief existence to the southward of a strong anticyclone, it caused intensification of the trade winds northeast of the islands. On the 5th to 8th, midway along the route from Honolulu to Balboa strong northeast trades, force 7–8, were encountered by the American Steamship *Steel Age*.

In the Gulf of Tehuantepec norther gales occurred as follows: of force 7 on the 23d and 24th; of force 9 on the 14th and 15th.

Reports from Manila indicate the existence of a damaging typhoon over the central Philippines on December 2.

Fog.—Ships reported fog on 6 days in December—on 1 day near San Diego, Calif., and on the other days in widely separated localities along the upper and middle steamship routes.

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, December 1936

[For description of tables and charts, see REVIEW, January, p. 29]

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	° F.	° F.		° F.			° F.		In.	In.		In.		In.
Alabama	50.3	+2.8	Pushmataha	80	6	Riverton	18	13	7.10	+2.15	Centerville	11.55	Newton	3.89
Arizona	44.9	+.7	Florence	88	22	St. Johns	−5	31	1.97	+.77	Williams	6.16	Yuma Valley	T
Arkansas	45.5	+2.8	Magnolia	78	30	Gilbert	13	12	5.32	+1.04	Yancopin	9.31	Lead Hill	2.14
California	44.2	−1.3	2 stations	82	[1] 14	Bridgeport	−19	29	5.01	+1.31	Squirrel Inn	21.44	Tule Lake	.14
Colorado	28.6	+3.1	Meeker (near)	72	17	Hermit (near)	−23	27	.92	+.02	Pagosa Springs (near).	10.30	3 stations	T
Florida	61.7	+1.9	2 stations	89	6	Cottage Hill	26	[1] 20	3.01	+.21	Garniers (near)	7.45	Everglades	.18
Georgia	49.7	+2.0	Fargo	83	31	2 stations	18	[1] 1	6.26	+1.93	Cornelia	12.00	Fitzgerald	2.80
Idaho	28.5	+2.5	Lapwai	65	19	Deadwood Dam	−24	31	1.85	−.17	Roland	9.59	Indian Cove	.06
Illinois	35.1	+4.6	Jacksonville	67	25	Freeport	−13	7	2.95	+.60	Wheaton	4.32	Keithsburg	1.52
Indiana	35.5	+3.3	Shoals	74	30	3 stations	0	7	2.88	+.03	La Porte	4.81	Farmersburg	1.05
Iowa	28.7	+4.7	Keosauqua	65	25	Rock Rapids	−16	7	1.55	+.36	Muscatine	2.94	Waukon	.61
Kansas	37.7	+4.8	Valley Falls	69	25	2 stations	−1	[1] 2	1.16	+.30	Eureka	4.05	Smith Center	.08
Kentucky	40.5	+2.8	Cumberland	70	29	Mammoth Cave	10	13	4.51	+.55	Mammoth Cave	7.26	Grant	1.77
Louisiana	53.4	+1.0	2 stations	82	6	Ruston	21	13	4.92	−.46	Angola	11.79	Burrwood	2.36
Maryland-Delaware	37.6	+1.9	do	70	27	Oakland, Md	−10	23	5.51	+2.19	Lutherville, Md	8.10	Oakland, Md	3.68
Michigan	28.7	+3.0	Kalamazoo	69	30	2 stations	−22	7	2.23	+.18	East Jordan	4.49	St. Ignace	.52
Minnesota	17.7	+2.2	2 stations	57	26	Pokegama Falls	−42	7	1.46	+.66	Pigeon River Bridge	3.90	Angus	.21
Mississippi	49.8	+1.5	do	80	6	2 stations	20	13	6.54	+1.19	Waynesboro	10.28	Biloxi	3.72
Missouri	38.4	+4.3	do	69	24	Grant City	−7	7	2.83	+.67	Dexter	6.29	Meramec Park	1.06
Montana	23.4	+.4	Simpson (near)	68	19	Outlook	−41	6	.98	+.10	Heron	7.27	Deer Lodge	.11
Nebraska	29.8	+3.0	Syracuse	69	25	Merriman	−17	6	.69	−.01	Falls City	2.00	Waterloo	.02
Nevada	32.4	+1.6	Logandale	70	23	San Jacinto	−10	29	1.79	+.80	Marlette Lake	7.27	Thorne	.26
New England	29.5	+3.0	2 stations	62	31	First Conn. Lake, N. H.	−20	8	6.13	+2.80	Kingston, R. I	11.59	Burlington, Vt	2.20
New Jersey	37.5	+3.8	Charlotteburg	67	26	Layton	−3	1	6.29	+2.64	Long Branch	8.87	Little Falls	2.73
New Mexico	35.3	+1.4	Hagerman	78	9	Lee Ranch	−24	18	.59	−.10	McGaffey Ranger Station.	3.97	Hagerman	.00
New York	30.5	+3.8	Bedford Hills	66	[1] 26	Stillwater Reservoir	−31	1	3.45	+.43	Bridgehampton	9.81	Penn Yan	.86
North Carolina	44.6	+2.0	3 stations	75	[1] 11	Mount Mitchell	8	20	6.31	+2.44	Swansboro	14.80	Montreat	3.38
North Dakota	15.0	+2.3	Mott	59	23	Willow City	−36	30	.43	−.07	Fullerton	1.23	Carrington	T
Ohio	35.4	+3.8	Portsmouth	68	27	Jefferson	−1	1	2.31	−.44	Peebles	4.53	2 stations	1.12
Oklahoma	44.1	+4.3	Spavinaw	73	28	Goodwell	4	3	1.73	+.04	Smithville	5.07	Kenton	.14
Oregon	34.3	+1.0	Arlington	68	23	Austin	−15	1	3.58	−.21	Valsetz	23.30	Owyhee Dam	.03
Pennsylvania	34.5	+3.2	Marcus Hook	74	25	Emporium	−11	1	4.19	+1.07	Phoenixville	7.15	Erie	1.19
South Carolina	47.6	+1.0	Orangeburg	78	26	Chester	19	21	5.60	+1.95	Caesars Head	13.30	Charleston	2.99
South Dakota	22.7	+1.9	Vale	68	22	Lemmon	−27	6	.36	−.19	Sioux Falls	1.81	Strool	T
Tennessee	43.8	+3.1	Madisonville	75	29	Dover	11	12	6.44	+1.84	Madisonville	9.54	Elizabethton	2.85

[1] Other dates also.

Condensed climatological summary of temperature and precipitation by sections, December 1936—Continued

Section	Temperature: Section average	Temperature: Departure from the normal	Monthly extremes: Station	Highest	Date	Station	Lowest	Date	Precipitation: Section average	Precipitation: Departure from the normal	Greatest monthly: Station	Amount	Least monthly: Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Texas	51.2	+2.3	2 stations	87	[1] 3	2 stations	10	2	1.94	−.34	Bon Wier	7.82	Langtry	.00
Utah	29.2	+2.7	St. George	66	25	Duchesne	−16	30	2.08	+.99	Silver Lake	6.30	Manila	.22
Virginia	39.4	+1.4	2 stations	72	[1] 26	Burkes Garden	2	23	5.07	+1.95	Pinnacles	7.66	Mt. Weather	2.55
Washington	35.5	+2.9	7 stations	65	[1] 6	Deer Park (near)	−10	29	6.39	+.59	Big Four	29.57	Oroville	.10
West Virginia	37.2	+2.6	3 stations	70	[1] 25	Bayard	−8	23	4.02	+.68	Terra Alta	6.30	Wellsburg	2.32
Wisconsin	23.7	+3.3	2 stations	58	30	Solon Springs	−36	11	1.84	+.52	Beloit	3.80	Park Falls	.40
Wyoming	24.1	+2.4	Chugwater	64	14	Nine Mile Creek	−27	31	.71	−.03	Bechler River	4.37	Powell	T
Alaska (November)	18.7	+5.0	Wrangell	65	12	Hot Springs	−50	17	5.82	+2.74	Little Port Walter	59.08	Barrow	T
Hawaii	69.3	−.4	2 stations	87	[1] 11	Kanalohuluhulu	45	28	17.27	+7.61	Piihonua	60.00	Pokii Ridge	.03
Puerto Rico	73.1	−1.1	Utuado	94	[1] 1	Guineo Reservoir	40	1	7.03	−.20	La Mina (El Yunque).	32.63	Mona Island	.00

[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, December 1936*

District and station	Elevation of instruments: Barometer above sea level	Elevation: Thermometer above ground	Elevation: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Departure from normal	Days with 0.01 inch or more	Wind: Total movement	Prevailing direction	Maximum velocity: Miles per hour	Maximum velocity: Direction	Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
New England							32.6	+3.1										78	6.95	+3.5										6.7		
Eastport	76	67	85	30.14	30.22	+0.24	28.6	+2.3	52	20	37	4	23	20	35	28	26	86	5.62	+1.9	16	10,039	nw.	46	s.	20	6	6	19	7.1	0.8	0.0
Greenville, Maine	1,070	6	40	29.01	30.21	------	19.8	------	48	28	29	−7	2	10	37	20	18	----	4.81	------	12	5,002	se.	42	------	28	5	7	19	----	11.5	6.0
Portland, Maine	103	82	117	30.11	30.24	+.21	31.0	+3.4	54	28	39	8	23	23	37	27	21	67	8.09	+4.1	15	6,820	n.	45	se.	20	12	7	12	5.4	2.4	.0
Concord	289	60	----	------	------	------	29.6	+2.8	55	28	38	6	1	21	34	----	----	----	7.64	+4.5	13	------	nw.	----	------	---	13	10	8	----	9.0	-----
Burlington	403	11	48	29.77	30.23	+.18	25.6	+1.2	53	28	35	−5	8	17	41	23	20	80	2.20	+.3	11	8,675	s.	35	s.	16	4	9	18	7.5	15.3	.0
Northfield	876	12	60	29.26	30.25	+.20	23.0	+2.6	57	27	34	−15	8	12	43	21	18	82	3.57	+1.1	16	6,300	s.	32	sw.	28	4	9	18	7.4	18.0	T
Boston [1]	29	31	50	30.20	30.23	+.18	35.0	+2.5	59	31	43	10	1	27	36	32	28	76	8.19	+4.7	16	8,148	nw.	37	s.	20	8	5	18	6.8	.7	.0
Nantucket	12	14	90	30.21	30.22	+.17	39.8	+4.0	55	31	46	17	23	34	23	37	34	82	7.04	+3.3	12	12,163	w.	41	e.	3	7	3	21	7.7	T	.0
Block Island	26	11	46	30.19	30.22	+.16	39.0	+3.0	56	31	45	16	1	33	27	37	34	83	9.42	+5.6	15	13,771	n.	44	se.	20	8	6	17	6.8	T	.0
Providence	160	215	251	30.06	30.24	+.18	35.6	+4.0	61	31	44	10	1	28	34	32	28	75	9.44	+6.1	15	8,863	nw.	47	se.	20	11	4	16	6.1	T	.0
Hartford	159	70	104	30.07	30.26	+.19	35.0	+5.2	57	28	43	10	1	27	30	----	----	----	6.88	+2.9	14	6,519	n.	28	nw.	7	11	5	15	6.0	.9	.0
New Haven	106	74	153	30.13	30.26	+.19	36.0	+3.5	58	28	43	11	1	29	32	32	27	71	8.34	+4.3	14	7,620	n.	30	e.	20	10	8	13	6.1	.7	.0
Middle Atlantic States							38.9	+3.4										75	5.04	+1.7										6.5		
Albany	97	97	112	30.15	30.26	+.18	32.0	+3.5	56	27	40	4	1	24	27	29	23	70	2.90	+.3	13	5,767	s.	29	se.	20	8	6	17	6.6	3.8	.0
Binghamton	871	57	79	29.29	30.25	+.16	32.4	+4.2	60	26	41	−6	1	24	30	----	----	----	1.99	−.3	16	5,091	nw.	24	w.	21	4	5	22	8.2	4.1	.0
New York	314	415	454	29.89	30.25	+.16	39.2	+4.2	62	26	46	12	1	32	27	35	30	60	7.03	+3.4	13	11,642	n.	50	se.	20	9	9	13	5.9	T	.0
Harrisburg	374	94	104	29.85	30.27	+.15	36.1	+3.4	59	27	42	12	1	30	22	32	27	71	6.06	+3.0	11	5,462	ne.	24	s.	20	9	5	17	6.2	5.2	.0
Philadelphia	114	174	367	30.14	30.27	+.16	39.6	+3.3	62	26	47	15	1	32	26	36	31	72	4.83	+1.4	12	9,960	n.	37	sw.	20	9	8	14	6.3	.3	.0
Reading	323	283	306	29.90	30.27	------	38.6	+6.4	65	27	46	13	1	32	27	34	29	71	4.38	+.8	13	8,703	n.	46	se.	19	9	6	16	6.3	2.7	.0
Scranton	805	72	104	29.36	30.26	+.16	34.4	+3.7	60	26	42	5	1	27	27	31	25	70	2.75	−.3	10	5,074	n.	23	sw.	20	6	9	16	7.1	3.4	.0
Atlantic City	52	37	172	30.19	30.25	+.15	41.2	+4.8	64	28	48	15	1	34	27	38	33	75	7.65	+3.7	13	13,166	nw.	51	se.	19	4	7	20	7.3	T	.0
Sandy Hook	22	10	57	30.22	30.24	------	39.2	+4.0	60	28	45	18	1	33	23	36	32	79	6.97	+2.9	13	12,072	sw.	46	s.	31	11	6	14	6.1	T	.0
Trenton	190	88	106	30.05	30.26	------	37.9	+3.5	61	26	46	11	1	30	28	34	30	75	5.44	+2.1	13	7,75[illegible]	n.	29	e.	19	13	6	12	5.6	1.0	.0
Baltimore	123	100	215	30.13	30.27	+.14	40.8	+3.6	64	27	48	15	1	34	28	36	30	71	7.10	+3.7	14	7,545	n.	35	w.	20	11	5	15	6.0	2.8	.0
Washington	112	62	85	30.14	30.27	+.14	39.8	+3.2	65	27	47	14	1	32	30	35	30	73	5.23	+1.9	13	5,346	nw.	21	sw.	20	11	5	15	6.1	1.5	.0
Cape Henry	18	8	54	30.21	30.23	------	45.6	+1.9	70	27	52	29	24	39	32	42	39	84	5.43	+2.0	13	9,750	n.	35	n.	7	9	6	16	6.5	T	.0
Lynchburg	686	148	184	29.51	30.28	+.14	40.9	+1.4	65	26	49	18	1	33	36	36	32	76	5.35	+2.1	17	4,833	n.	31	nw.	20	7	6	18	6.7	1.0	.0
Norfolk	91	80	125	30.15	30.25	+.12	46.2	+3.1	71	27	53	27	1	39	32	42	39	82	4.88	+1.5	15	7,390	n.	36	w.	20	8	4	19	6.9	T	.0
Richmond	144	11	52	30.11	30.27	+.13	41.4	+1.6	70	27	49	18	1	34	36	37	33	80	4.34	+1.0	16	6,018	ne.	28	nw.	20	9	5	17	6.5	T	.0
Wytheville	2,304	40	55	------	30.25	+.10	36.7	+1.4	58	6	45	18	23	28	34	----	----	84	3.31	+.4	16	4,453	e.	26	w.	---	6	5	20	----	8.9	.0
South Atlantic States							49.4	+2.0										84	5.24	+1.8										7.2		
Asheville	2,253	89	104	27.82	30.24	+.08	42.4	+4.6	60	26	51	22	13	34	33	38	34	78	4.84	+1.6	14	6,425	n.	26	se.	19	5	9	17	6.9	6.2	.0
Charlotte	779	63	86	29.38	30.24	+.08	45.1	+2.1	67	26	52	23	1	38	28	41	37	79	5.53	+1.7	16	5,307	ne.	22	sw.	20	8	3	20	7.3	T	.0
Greensboro	886	6	56	29.27	30.25	------	41.0	------	65	26	49	21	1	33	36	37	35	88	5.31	------	15	6,026	ne.	23	w.	20	8	4	19	7.1	.2	.0
Hatteras	11	5	50	------	30.21	+.08	51.7	+1.6	70	27	57	39	21	47	25	----	----	86	10.19	+6.0	15	10,914	n.	38	se.	2	11	3	17	----	.0	.0
Raleigh	376	103	146	29.82	30.24	+.09	45.2	+2.2	68	27	53	25	8	38	32	42	39	85	6.52	+2.9	14	6,723	ne.	24	w.	7	6	7	18	7.0	T	.0
Wilmington	72	73	107	30.14	30.22	+.07	50.6	+1.5	72	27	59	34	1	43	31	47	44	85	6.51	+3.7	13	6,450	ne.	30	w.	19	7	5	19	7.0	.0	.0
Charleston	48	11	92	30.14	30.19	+.04	52.2	+.5	73	31	59	36	1	46	24	48	46	86	2.99	+.3	10	8,054	n.	27	sw.	19	3	8	20	7.6	.0	.0
Columbia, S. C.	347	70	91	29.84	30.23	+.07	49.4	+2.2	72	6	57	30	1	42	33	44	40	78	4.62	+1.6	14	5,980	ne.	25	sw.	19	6	7	18	7.0	.0	.0
Greenville, S. C.	1,039	139	----	------	------	------	44.7	+2.5	64	18	52	24	8	38	30	----	----	----	5.34	+.5	15	------	ne.	----	------	---	8	5	18	----	.0	.0
Augusta	182	62	77	30.00	30.20	+.04	50.6	+2.5	75	6	59	30	21	42	35	46	43	82	5.82	+2.6	14	4,653	ne.	20	nw.	7	5	6	20	7.5	.0	.0
Savannah	65	73	152	30.12	30.18	+.03	53.8	+1.4	75	7	61	36	21	46	27	49	47	87	3.34	+.4	15	7,498	ne.	30	nw.	20	6	6	19	7.5	.0	.0
Jacksonville	43	86	110	30.11	30.16	+.02	57.2	+.9	79	6	65	37	21	49	29	53	51	90	1.98	−1.0	10	6,360	ne.	21	ne.	1	6	7	18	7.3	.0	.0
Florida Peninsula							69.9	+3.4										82	1.99	+0.2										5.3		
Key West	22	10	64	30.05	30.07	−.01	73.2	+2.9	84	12	78	60	21	68	15	68	66	83	1.67	.0	9	7,183	ne.	24	nw.	15	15	9	7	4.5	.0	.0
Miami	25	124	168	30.06	30.09	−.02	71.6	+3.6	81	7	77	49	21	66	24	66	63	76	2.08	+.4	10	7,393	e.	29	ne.	25	10	11	10	5.3	.0	.0
Tampa	35	88	197	30.08	30.12	.00	64.8	+3.7	83	31	73	43	21	57	26	59	57	87	2.22	+.2	8	8,263	ne.	24	e.	26	8	11	12	6.0	.0	.0
Titusville	43	5	36	30.06	30.11	------	64.0	------	84	7	74	37	21	54	31	----	----	----	1.15	------	10	------	nw.	----	------	---	7	10	14	----	.0	.0

[1] Observations taken at airport.

TABLE 1.—*Climatological data for Weather Bureau stations, December 1936*—Continued

District and station	Elevation of instruments			Pressure			Temperature of the air												Precipitation			Wind										
																								Maximum velocity								
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Total	Departure from normal	Days with 0.01 inch or more	Total movement	Prevailing direction	Miles per hour	Direction	Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
East Gulf States							52.1	+2.1										82	5.46	+0.6										6.9		
Atlanta [1]	976	5	53	29.14	30.19	+.03	46.6	+1.9	66	6	54	29	13	39	27	42	39	82	7.98	+3.3	17	6,604	ne.	27	ne.	18	4	7	20	7.5	0.0	0.0
Macon	370	79	87	29.78	30.19	+.03	50.9	+3.4	76	6	59	31	2	42	33	46	42	79	4.60	+.6	12	5,483	ne.	24	ne.	1	6	7	18	7.2	.0	.0
Thomasville	273	49	58	29.86	30.16	+.01	55.1	+2.6	78	29	64	33	20	47	31	50	48	85	4.10	−.2	7		e.				8	5	18		.0	.0
Apalachicola	35	11		30.10	30.14		55.8	+.1	72	3	62	36	20	50	22	52	51	88	3.81	−1.3	9	6,922	e.	28	ne.	1	6	5	20	6.9	.0	.0
Pensacola	56	149	185	30.09	30.15	.00	55.3	+1.3	72	28	62	34	20	49	26	52	50	80	2.48	−2.2	11	9,466	ne.	32	s.	19	8	11	12	6.1	.0	.0
Anniston	741	9					48.5	+4.3	70	6	58	24	13	40	34				9.23	+4.2	14		se.				9	6	16		.0	.0
Birmingham	700	11	48	29.39	30.18	+.02	49.0	+2.6	71	28	57	26	13	41	26	44	40	80	7.78	+2.6	16	5,998	e.	30	se.	6	9	4	18	6.5	.0	.0
Mobile	57	86	105	30.09	30.15	.00	54.2	+2.0	75	28	62	32	13	46	31	50	47	84	4.03	−1.0	10	7,660	n.	26	nw.	7	5	9	17	7.0	.0	.0
Montgomery	218	92	105	29.93	30.19	+.03	52.0	+2.6	76	6	60	31	20	44	25	47	44	80	6.63	+1.8	15	5,770	e.	21	sw.	6	6	4	21	7.6	.0	.0
Meridian	375	67	92	29.76	30.17	+.01	50.4	+2.7	76	6	59	27	13	42	34	45	42	81	6.85	+1.6	14	4,612	ne.	22	nw.	30	6	7	18	6.9	.0	.0
Vicksburg	247	65	73	29.90	30.17	+.02	51.4	+1.4	72	30	59	28	12	43	20	46	41	74	4.15	−1.2	11	5,369	n.	25	s.	30	7	4	20	7.1	.0	.0
New Orleans	53	76	84	30.09	30.15	+.02	56.2	+.6	80	6	64	36	13	49	25	51	48	80	3.86	−.9	7	5,552	ne.	20	nw.	10	7	5	19	6.6	.0	.0
West Gulf States							53.0	+2.5										77	3.01	0.0										5.5		
Shreveport	249	92	227	29.88	30.16	+.03	52.0	+2.9	75	17	61	31	12	43	32	46	42	73	4.43	+.1	8	7,761	se.	52	nw.	6	10	9	12	5.7	.0	.0
Bentonville	1,303	12	38	28.69	30.08	−.05	43.7	+6.2	64	27	53	17	7	35	30				3.25	+.9	10	5,111	s.	24	w.	30	9	7	15		T	.0
Fort Smith	457	70	94	29.64	30.13	.00	45.8	+3.7	70	27	54	24	7	38	28	41	36	72	3.10	+.3	9	6,138	e.	27	w.	30	10	7	14	5.9	.0	.0
Little Rock	357	94	102	29.78	30.17	+.03	46.1	+1.9	68	24	54	24	7	38	25	41	36	73	4.90	+.8	11	5,264	e.	22	s.	30	8	6	17	6.4	T	.0
Austin	605	136	148	29.48	30.11		53.3	+2.3	78	17	64	29	12	43	37	48	44	76	1.88	−.8	8	5,251	n.	23	n.	18	12	8	11	5.2	.0	.0
Brownsville	57	88	96	30.00	30.06		62.8	+1.6	80	27	71	39	14	55	27	58	56	84	2.41	+.8	10	8,065	se.	30	s.	17	9	12	10	5.3	.0	.0
Corpus Christi	20	11	78	30.08	30.10	−.02	60.0	+2.0	78	5	67	39	14	53	29	55	53	83	1.05	−.4	8	7,844	s.	32	n.	4	13	3	15	5.5	.0	.0
Dallas	512	220	227	29.55	30.11		50.3		69	27	59	28	7	42	27	45	40	73	2.17	−.2	8	7,836	se.	33	w.	30	15	5	11	5.1	.0	.0
Fort Worth	670	92	110	29.39	30.12	.00	50.4	+2.9	72	28	60	26	7	41	32				1.84	.0	6	6,983	s.	31	n.	18	16	5	10	4.4	.0	.0
Galveston	54	106	114	30.07	30.13	+.01	56.1	−.3	72	5	61	38	12	51	23	53	51	88	3.11	−.6	7	7,920	e.	34	s.	10	12	9	10	5.3	.0	.0
Houston	138	292	314	29.99	30.14		55.8	+1.4	77	5	64	32	12	48	29				5.81	+1.6	10	9,197	se.	27	nw.	30	7	10	14	6.0	.0	.0
Palestine	510	64	72	29.60	30.14	+.02	52.6	+2.7	75	17	62	27	7	43	35	48	44	78	3.01	−.7	9	5,572	s.	23	se.	5	11	8	12	5.5	.0	.0
Port Arthur	34	58	66	30.09	30.13		54.5		72	6	62	32	12	48	27				3.46	−1.8	8	8,013	e.	34	s.	30	9	6	16	6.1	.0	.0
San Antonio	693	242	301	29.36	30.00	−.02	56.4	+2.7	77	17	65	34	12	48	28	50	44	68	1.75	+.1	9	7,789	e.	30	n.	18	9	10	12	5.3	.0	.0
Ohio Valley and Tennessee							40.0	+3.4										76	3.81	+0.3										6.4		
Chattanooga	762	71	214	29.37	30.20	+0.04	47.2	+3.9	69	29	55	29	13	40	28	42	36	71	7.00	+1.9	17	5,606	ne.	24	w.	19	5	11	15	6.7	T	.0
Knoxville	995	66	84	29.13	30.21	+.05	44.9	+4.6	68	30	53	23	13	37	26	40	36	76	6.21	+1.7	13	4,188	e.	19	w.	19	8	7	16	6.6	.6	.0
Memphis	399	78	86	29.74	30.17	+.02	46.2	+2.6	68	30	54	23	7	39	28	41	36	73	6.84	+2.3	11	5,199	e.	24	n.	6	9	7	15	6.3	.2	.0
Nashville	546	168	188	29.62	30.21	+.06	43.8	+2.8	68	29	52	24	12	35	30	39	35	76	4.72	+.5	12	6,308	se.	38	s.	30	8	4	19	6.8	T	.0
Lexington	989	6																														
Louisville	525	188	234	29.63	30.23	+.09	39.6	+2.0	66	30	48	16	7	32	26	36	32	76	2.77	−1.0	12	6,814	s.	34	se.	30	10	9	12	5.7	1.6	.0
Evansville	431	76	116	29.72	30.21	+.08	40.1	+3.0	65	30	47	15	7	33	30	36	31	72	2.10	−1.4	11	6,212	s.	32	s.	30	11	5	15	5.8	.5	.0
Indianapolis	822	194	230	29.29	30.20	+.08	35.8	+3.6	61	30	44	9	7	28	34	32	27	72	3.20	+.2	11	8,313	s.	33	s.	30	9	7	15	6.3	3.8	.0
Terre Haute	575	63	149	29.55	30.18		36.6		63	30	44	9	7	29	35	34	30	79	3.44	+.5	10	7,212	s.	37	sw.	30	9	8	14	5.9	5.6	.0
Cincinnati	627	11	51	29.52	30.23	+.10	37.7	+4.3	62	30	46	16	7	30	26	33	30	78	2.60	−.4	11	5,646	s.	24	se.	30	10	3	18	6.5	1.2	.0
Columbus	822	90	210	29.32	30.22	+.10	37.0	+4.6	62	30	44	17	7	30	22	33	28	74	1.79	−.9	9	6,911	s.	31	sw.	20	9	6	16	6.3	3.8	.0
Dayton	900	58	153	29.26	30.22		36.7	+4.1	62	30	44	16	7	30	24				2.02	−.7	11	6,415	sw.	29	sw.	27	7	9	15	6.3	2.3	.0
Elkins	1,947	59	78	28.14	30.28	+.16	36.9	+4.2	61	27	48	10	23	26	38	32	29	81	4.01	+.6	16	4,508	se.	35	sw.	20	5	7	19	7.4	2.6	.0
Parkersburg	637	77	84	29.59	30.27	+.13	38.7	+3.5	66	27	48	17	13	30	31	34	31	82	3.30	+.3	11	4,347	se.	21	nw.	6	8	9	14	6.4	1.2	.0
Pittsburgh [1]	1,273	39	54	28.82	30.22	+.11	35.8	+1.6	61	27	43	10	1	28	27	32	27	76	3.39	+.5	11	8,183	s.	31	w.	20	5	8	18	7.2	9.3	.0
Lower Lake Region							33.0	+3.6										76	2.12	−0.6										7.1		
Buffalo	768	243	280	29.34	30.20	+.14	33.8	+4.0	58	31	40	6	1	28	22	31	28	79	1.74	−1.6	10	12,535	s.	50	sw.	21	6	9	16	7.1	6.2	.0
Canton	448	10	61	29.70	30.20		25.0	+2.3	58	31	36	−15	1	14	37	23	21	86	2.06	−.6	13	7,396	sw.	35	sw.	20	9	4	18	6.9	10.3	.0
Ithaca	836	77	100	29.29	30.22		32.4	+3.4	59	27	40	−5	1	24	29	29	25	75	2.18	−.2	13	8,313	se.	37	se.	19	3	5	23	8.0	7.1	.0
Oswego	335	71	85	29.83	30.21	+.15	31.4	+2.4	59	27	39	0	1	24	31	29	24	72	2.48	−1.0	9	8,489	se.	33	nw.	20	3	7	21	7.9	15.6	.0
Rochester	523	86	102	29.62	30.22	+.16	34.2	+4.9	62	27	41	11	1	28	23	30	25	71	2.93	+.2	13	6,924	sw.	31	sw.	20	5	8	18	7.5	12.2	.0
Syracuse	596	65	79	29.57	30.24	+.17	33.2	+4.2	62	27	41	1	1	25	30				1.89	−1.2	15	6,175	s.	27	s.	6	5	5	21	7.6	10.8	.0
Erie	714	130	166	29.40	30.20	+.13	35.4	+3.5	62	27	42	8	1	29	24	32	27	73	1.19	−1.6	10	10,755	s.	46	se.	19	8	6	17	6.9	3.2	.0
Cleveland	762	267	318	29.35	30.20	+.11	36.4	+5.2	64	27	43	11	1	30	25	33	28	72	1.64	−.8	11	12,567	s.	44	w.	20	5	8	18	7.1	4.3	.0
Sandusky	629	5	67	29.50	30.20	+.11	35.2	+4.0	63	30	42	13	7	28	25				1.74	−.5	9	7,495	sw.	27	w.	20	7	6	18	6.7	2.4	.0
Toledo	628	79	87	29.50	30.21	+.13	33.6	+3.2	60	30	40	10	7	27	26	31	27	76	2.82	+.5	11	7,397	sw.	27	w.	31	11	4	16	6.3	5.0	.0
Fort Wayne	857	69	84	29.24	30.20		33.2	+3.5	60	30	40	8	7	26	29	30	27	80	2.68	+.1	11	6,619	s.	30	s.	30	9	5	17	6.4	2.8	.0
Detroit [1]	626	5	78	29.48	30.19	+.12	32.2	+2.9	58	30	39	8	7	25	29	30	26	78	2.04	−.3	11	8,117	sw.	32	sw.	31	7	6	18	6.9	1.6	.0
Upper Lake Region							27.9	+3.5										82	2.31	+0.3										7.4		
Alpena	609	13	89	29.44	30.12	+.10	29.1	+4.3	53	30	35	6	7	23	26	27	24	81	1.67	−.4	13	8,854	s.	34	se.	30	4	5	22	7.7	7.0	.0
Escanaba	612	54	60	29.41	30.10	+.07	24.7	+2.3	46	27	32	−11	7	18	37	24	20	82	2.31	+.6	14	7,232	s.	30	nw.	20	6	4	21	7.6	17.3	T
Grand Rapids	707	70	244	29.36	30.16	+.11	32.4	+3.9	60	30	39	8	7	26	29	30	26	79	3.72	+1.2	12	9,278	sw.	48	sw.	30	7	5	19	7.0	6.5	.0
Lansing	878	5	90	29.19	30.16		29.8	+2.6	58	30	37	6	7	22	29	28	26	86	1.99	−.1	11	7,547	sw.	29	s.	30	6	8	17	6.9	5.5	.0
Ludington	637	5	54	29.41	30.13		31.0	+2.6	59	30	37	7	7	25	30	29			3.11	+1.6	10		s.				10	4	17		7.3	.0
Marquette	734	77	111	29.23	30.06	+.04	26.2	+3.6	51	30	32	−5	7	20	25	25	22	85	1.15	−1.5	12	8,404	s.	45	sw.	31	3	6	22	8.2	5.3	T
Sault Sainte Marie	614	11	52	29.40	30.12	+.12	24.4	+4.9	45	30	31	2	7	18	28	23	21	85	3.40	+1.1	16	6,938	se.	31	nw	27	1	2	28	9.1	19.9	5.4
Chicago	673	7	131	29.42	30.17	+.09	34.0	+5.2	60	30	41	1	7	27	36	31	27	77	[illegible]	+.5	8	8,373	sw.	35	sw.	30	11	4	16	6.0	.8	.0
Green Bay	617	109	141	29.40	30.09	+.05	26.4	+4.1	55	30	34	−13	7	18	41	23	21	80	1.03	−.7	10	8,435	sw.	31	sw.	31	7	4	20	7.5	4.1	.0
Milwaukee	681	97	221	29.37	30.13	+.07	31.1	+5.0	57	30	38	−6	7	24	39	29	24	75	2.14	+.4	7	10,458	w.	41	sw.	30	8	5	18	6.5	3.5	.0
Duluth	1,133	5	47	28.76	30.03	−.02	17.1	+1.2	39	23	25	−23	7	9	35	17	14	87	2.29	+1.1	17	9,687	w.	39	w.	30	5	4	22	7.6	14.9	2.9
North Dakota							14.6	+2.2										82	0.43	−0.2										6.2		
Morehead, Minn.	940	50	58	29.01	30.08	.00	14.2	+2.7	42	19	23	−18	6	5	32	14	12	88	.77	.0	11	6,906	s.	35	nw.	19	4	8	19	7.4	11.9	2.7
Bismarck	1,674	8	57	28.20	30.07	−.01	16.7	+2.0	54	23	25	−21	6	8	27	15	11	78	.21	−.4	6	6,509	nw.	35	nw.	19	11	7	13	5.9	3.8	.9
Devils Lake	1,478	11	44	28.40	30.06	.00	12.4	+2.9	48	23	21	−24	6	4	28	11	9	86	.29	−.2	6	6,878	nw.	38	nw.	19	9	8	14	6.2	3.7	1.0
Grand Forks	833	12	67				12.2		43	22	21	−23	6	3	31	11			.30		4		nw.	43	nw.	19	7	8	16		3.0	1.0
Williston	1,878	42	50	27.98	30.05	−.01	15.0	+1.2	49	22	25	−26	6	5	35	13	9	76	.45	−.1	4	6,090	sw.	37	nw.	19	9	15	7	5.3	6.0	4.6

[1] Observations taken at airport.

TABLE 1.—*Climatological data for Weather Bureau stations, December 1936*—Continued

District and station	Elevation of instruments			Pressure			Temperature of the air										Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation			Wind					Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range					Total	Departure from normal	Days with 0.01 inch or more	Total movement	Prevailing direction	Maximum velocity: Miles per hour	Maximum velocity: Direction	Maximum velocity: Date						
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
Upper Mississippi Valley							31.8	+4.7										78	2.37	+0.7										6.2		
Minneapolis	919	105	208	29.04	30.06		22.6	+3.0	51	26	31	−14	6	14	37	21	18	83	1.78	+.8	10	8,210	w.	36	nw.	19	7	6	18	7.1	11.2	1.5
La Crosse	714	11	48	29.31	30.12	+.04	26.2	+3.9	55	25	35	−12	7	18	36	24	20	80	1.47	+.1	8	4,509	s.	21	sw.	30	9	3	19	6.9	5.4	.0
Madison	974	70	78	29.04	30.14	+.06	27.4	+4.6	54	30	35	−10	7	20	36	26	23	85	2.33	+.7	11	7,091	s.	26	sw.	30	8	4	19	6.6	6.2	.0
Charles City	1,015	10	51	29.00	30.12	+.02	25.3	+4.9	55	26	34	−9	6	17	34	23	20	83	1.67	+.4	6	5,529	se.	25	w.	30	8	5	18	6.4	6.5	.0
Davenport	606	66	161	29.48	30.16	+.06	33.0	+5.9	59	30	41	−3	6	25	38	29	25	75	2.72	+1.2	6	7,614	sw.	38	sw.	30	9	8	14	5.9	2.5	.0
Des Moines	861	5	99	29.20	30.13	+.02	30.6	+4.6	58	26	39	−4	7	22	30	28	25	81	1.54	+.3	5	7,007	s.	29	w.	30	6	10	15	6.7	4.2	.0
Dubuque	700	60	79	29.37	30.15	+.05	29.2	+4.5	58	25	38	−8	7	21	39	26	23	79	2.03	+.6	6	4,956	s.	24	nw.	20	10	5	16	6.3	4.8	.0
Keokuk	614	64	78	29.49	30.17	+.05	35.6	+6.0	64	25	44	1	7	27	33	30	25	69	2.81	+1.4	7	6,071	sw.	27	w.	30	11	6	14	5.9	1.3	.0
Cairo	358	87	93	29.79	30.19	+.04	42.3	+4.5	66	30	50	18	7	34	31	38	33	74	4.06	+.7	10	6,042	s.	27	s.	30	10	4	17	6.2	T	.0
Peoria	609	11	45	29.50	30.18	+.07	33.8	+5.7	62	25	42	2	7	25	36	30	28	82	3.26	+1.5	8	5,813	s.	25	sw.	30	14	6	11	5.2	.6	.0
Springfield, Ill	636	5	191	29.48	30.18	+.06	35.8	+4.1	62	30	43	6	7	28	33	32	28	77	2.71	+.5	7	8,855	s.	35	s.	30	12	6	13	5.8	1.1	.0
St. Louis	568	179	303	29.55	30.18	+.05	39.4	+4.5	66	30	47	9	7	32	38	35	30	73	2.08	−.1	7	9,041	s.	36	s.	30	13	5	13	5.3	4.6	.0
Missouri Valley							32.6	+4.4										79	1.47	+0.3										6.1		
Columbia, Mo	784	6	84	29.30	30.15	+.03	38.3	+5.1	65	25	46	8	7	30	35				2.44	+.6	7	6,147	s.	25	w.	30	8	12	11	5.9	2.1	.0
Kansas City [1]	750	32	45	29.30	30.13	+.01	38.8	+6.3	65	25	47	8	6	30	31	34	30	77	2.35	+1.0	7	7,539	sw.	36	nw.	30	8	8	15	6.2	4.2	.0
St. Joseph	967	11	49	29.06	30.12		36.2		63	25	44	3	6	28	33	32	29	78	1.81	+.8	7	6,586	s.	27	nw.	6	11	7	13	5.5	3.8	.0
Springfield, Mo	1,324	98	104	28.70	30.14	+.01	41.4	+5.2	63	25	49	14	7	34	32	37	32	76	2.60	+.3	10	7,812	se.	30	se.	5	11	8	12	5.5	2.7	.0
Topeka	987	65	87	29.03	30.11		37.8	+5.8	66	25	47	8	6	29	34	34	31	78	1.55	+.6	6	7,254	s.	28	sw.	30	10	11	10	5.9	1.2	.0
Lincoln	1,189	11	81	28.80	30.11	−.01	31.8	+4.2	62	26	40	0	6	24	33	29	25	78	.88	+.1	3	6,714	s.	25	sw.	26	8	8	15	6.2	2.6	.3
Omaha [1]	982	31	44	29.03	30.12	+.01	29.4	+3.0	62	26	38	−3	6	21	31	27	24	82	1.12	+.2	4	7,379	s.	29	se.	5	6	8	17	6.5	6.3	.2
Valentine	2,598	47	54	27.28	30.10	.00	27.3	+2.7	63	25	38	−11	6	17	40	23	19	76	.26	−.4	6	5,993	w.	23	nw.	19	5	10	16	6.7	3.9	.0
Sioux City	1,138	64	106	28.84	30.10	−.02	27.0	+3.9	52	26	35	−7	6	19	33	25	22	85	1.16	+.3	6	7,032	se.	27	nw.	19	8	5	18	7.0	9.1	5.4
Huron	1,307	59	74	28.64	30.09	−.01	22.0	+3.3	50	23	30	−11	6	14	32	20	18	84	.49	−.1	7	6,410	se.	25	w.	31	10	10	11	5.9	7.0	T
Northern Slope							25.8	+2.1										73	0.71	0.0										6.8		
Havre	2,505	11	67	27.30	30.04	−.01	18.0	−2.4	56	22	28	−27	5	8	42	16	12	75	1.50	+.9	7	7,665	sw.	33	sw.	18	7	7	17	7.2	27.0	5.8
Helena	4,124	85	111	25.73	30.04	−.09	27.2	+3.0	56	22	35	−12	5	20	58	23	16	62	.69	−.1	10	6,028	sw.	32	sw.	13	1	6	24	8.3	11.7	3.1
Missoula	3,263	80	91				31.4	+6.9	56	19	39	3	6	24	45				.68	−.4	12	5,505	se.	29	e.	5	0	7	24	8.6	8.8	T
Kalispell	2,973	48	56	26.87	30.01	−.06	26.6	+1.7	52	22	34	−2	6	20	24	26	23	86	1.68	+.2	18	4,187	nw.	31	n.	5	0	5	26	9.1	13.7	1.2
Miles City	2,371	48	55	27.45	30.10	.00	20.6	−.4	47	19	30	−16	6	12	30	18	13	73	.35	−.3	6	4,378	s.	28	w.	18	4	14	13	6.5	6.6	1.5
Rapid City	3,259	50	58	26.57	30.11	+.02	27.2	+.3	65	23	38	−10	6	17	38	23	18	74	.05	−.4	2	4,839	n.	28	nw.	19	9	11	11	5.6	.6	.5
Cheyenne [1]	6,144	5	44	23.86	30.03	−.06	30.5	+2.0	60	14	42	−3	6	19	41	24	16	61	.41	−.1	6	9,784	nw.	50	nw.	7	10	14	7	4.9	4.2	T
Lander	5,372	60	68	24.56	30.08	−.07	24.8	+4.4	50	22	37	−14	31	12	39	20	14	69	.32	−.4	2	3,447	sw.	24	sw.	7	15	14	2	4.2	5.0	3.0
Sheridan	3,790	10	47	26.03	30.06		25.0		56	22	37	−9	6	13	59	21	16	74	.50	−.1	8	3,556	nw.	24	nw.	2	3	13	15	6.8	5.9	1.4
Yellowstone Park	6,241	12	46	23.79	30.13	−.03	21.1	+1.7	41	23	29	−7	29	13	38	19	15	73	1.21	+.4	17	6,134	sw.	27	sw.	6	2	5	24	8.1	20.4	6.0
North Platte	2,821	11	51	27.07	30.09	−.01	30.8	+4.1	57	15	42	−2	6	20	35	26	22	81	.43	−.1	4	4,804	w.	18	e.	4	8	11	12	5.8	4.2	.0
Middle Slope							38.2	+4.7										70	0.82	0.0										5.0		
Denver	5,292	106	113	24.66	30.02	−0.06	36.5	+4.2	64	14	48	9	31	26	39	28	17	50	0.37	−0.4	4	3,570	s.	20	ne.	27	12	14	5	4.3	7.7	2.3
Pueblo	4,685	80	86	25.25	30.03	−.05	35.3	+3.8	66	15	49	11	13	22	44	28	19	58	.34	−.2	2	5,092	nw.	33	nw.	7	16	9	6	4.2	3.6	.0
Concordia	1,392	50	58	28.60	30.12	+.01	35.4	+4.7	63	25	44	7	6	27	34	32	29	82	1.24	+.6	6	6,311	s.	25	n.	5	11	12	8	4.9	T	.0
Dodge City	2,509	10	86	27.42	30.09	−.01	37.9	+5.3	66	26	48	14	6	28	34	33	29	78	.85	+.3	3	8,428	s.	28	sw.	26	13	7	11	5.0	3.9	.0
Wichita	1,358	85	93	28.63	30.10	−.01	39.8	+5.2	65	25	48	15	6	32	32	36	32	77	.83	−.2	8	8,512	sw.	31	sw.	25	9	9	13	5.4	2.1	.0
Oklahoma City	1,214	10	47	28.78	30.09	−.02	44.3	+5.0	64	25	52	22	11	36	29	39	35	78	1.31	−.2	6	7,576	s.	24	se.	7	11	5	15	5.9	T	.0
Southern Slope							47.5	+3.4										65	0.53	−0.4										4.0		
Abilene	1,738	10	52	28.26	30.09	−.02	50.0	+4.0	73	29	60	29	11	40	37	42	36	67	.77	−.6	7	7,250	s.	25	se.	5	16	5	10	4.3	.0	.0
Amarillo	3,676	10	49	26.28	30.07	−.02	42.9	+5.9	67	15	54	25	11	32	33	35	27	64	.88	+.1	4	6,962	sw.	27	w.	30	17	5	9	4.1	.5	.0
Del Rio	960	63	71	29.06	30.06	−.04	54.4	+2.2	80	17	65	31	14	44	40	48	42	71	.32	−.4	6	6,142	se.	28	nw.	18	13	6	12	5.0	.0	.0
Roswell	3,566	75	85	26.40	30.07	.00	42.6	+1.4	69	16	57	18	31	28	44	34	26	59	.16	−.5	3	5,225	s.	34	nw.	17	21	7	3	2.8	.7	.0
Southern Plateau							42.5	+1.6										61	0.71	+0.1										3.6		
El Paso	3,778	82	101	26.24	30.08	+.05	46.8	+1.9	68	24	58	26	31	36	31	39	31	58	.51	.0	5	4,899	w.	27	sw.	29	19	8	4	2.9	.0	.0
Albuquerque	4,972	5	39	25.07	30.10		35.2	+.7	60	16	50	11	31	21	37	28	22	67	.13	−.3	3	5,244	n.	45	nw.	17	16	8	7	4.0	1.5	.0
Santa Fe	7,013	38	53	23.23	30.11	+.05	32.5	+1.8	56	23	43	12	6	22	28	26	20	64	.64	−.1	6	4,002	n.	21	n.	16	17	7	7	3.9	4.6	T
Flagstaff	6,907	10	59	23.31	30.01	−.05	31.5	+3.1	56	21	43	9	1	20	41	26		72	3.00		11	6,101	w.	30	s.	28	10	12	9		30.0	30.0
Phoenix	1,107	39	51	28.86	30.03	−.01	53.2	+1.2	75	19	66	33	13	41	36	44	35	58	2.12	+1.1	5	3,069	e.	15	se.	28	15	5	11	4.5	.0	.0
Yuma	141	9	54	29.90	30.05	.00	56.0	+.8	76	21	68	32	30	44	33	45	33	47	.14	−.4	1	4,457	n.	26	se.	27	20	8	3	2.8	.0	.0
Independence	3,957	5	26	25.99	30.09	−.03	38.4	−.9	60	9	51	16	30	26	36	31	22		2.10	+1.3	6		n.				20	5	6		17.3	11.0
Middle Plateau							31.2	+1.4										72	1.25	+0.4										5.6		
Reno	5,427	61	76	25.47	30.11	−.04	33.3	.0	59	23	44	9	31	22	34	29	22	65	1.49	+.5	7	3,371	sw.	24	s.	26	13	6	12	5.1	14.3	9.3
Tonopah	6,090	12	20				32.2		50	22	39	10	30	26	21	27	19	62	1.06		5		se.									
Winnemucca	4,344	18	56	25.63	30.12	−.06	30.8	+.8	53	24	43	1	4	19	42	26	22	76	1.58	+.5	9	5,245	ne.	23	w.	16	8	6	17	6.3	10.5	6.6
Modena	5,473	10	43	24.60	30.06	−.06	29.8	+1.7	55	23	42	−7	30	18	37	26	21	75	1.36	+.5	8	6,473	w.	29	w.	16	14	6	11	4.6	19.8	8.4
Salt Lake City [1]	4,227	32	46	25.74	30.00		33.6		55	24	41	16	5	26	25	30	26	77	1.88		11	6,247	se.	37	se.	27	8	4	19	6.8	17.7	6.7
Grand Junction	4,602	60	68	25.42	30.09	−.01	30.8	+3.3	50	28	40	8	6	21	31	26	22	74	.57	−.1	7	3,769	nw.	27	s.	28	11	11	9	5.2	2.8	.0
Northern Plateau							34.2	+3.5										76	1.06	−0.6										8.2		
Baker	3,471	48	53	26.46	30.10	−.06	30.4	+3.1	50	22	39	12	1	22	25	28	24	77	.35	−1.4	9	4,335	se.	19	sw.	6	2	5	24	8.4	1.5	T
Boise	2,739	79	87	27.21	30.13	−.07	35.2	+3.1	56	22	42	16	2	28	23	31	26	71	.78	−.8	9	3,737	se.	23	se.	26	4	5	22	7.7	2.6	.3
Pocatello	4,477	60	68	25.46	30.09	−.10	31.4	+3.7	52	24	39	7	4	24	32	28	23	71	.81	−.4	12	7,554	se.	32	s.	27	4	11	16	7.0	6.0	2.8
Spokane	1,929	101	110	27.92	30.02	−.06	33.0	+2.5	54	19	38	4	29	28	28	32	29	84	2.39	+.2	14	5,086	s.	24	s.	6	0	5	26	9.0	9.5	2.6
Walla Walla	991	57	65	28.94	30.03	−.09	40.5	+5.0	64	22	47	21	1	34	25	37	32	72	1.12	−.9	14	4,288	s.	24	sw.	18	1	3	27	9.1	.8	.2
Yakima	1,076	58	67	28.84	30.02		34.5	+3.8	63	18	43	13	2	26	34	32	29	78	.93	−.4	13	3,230	nw.	32	sw.	6	1	10	20	7.9	6.7	2.6

[1] Observations taken at airport.

TABLE 1.—*Climatological data for Weather Bureau stations, December 1936*—Continued

District and station	Elevation of instruments			Pressure			Temperature of the air													Precipitation			Wind									
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Total	Departure from normal	Days with 0.01 inch or more	Total movement	Prevailing direction	Maximum velocity: Miles per hour	Maximum velocity: Direction	Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
North Pacific Coast Region							44.0	+1.5										87	6.60	−0.7										8.6		
North Head	211	11	56	29.78	30.02	−.01	44.2	+.1	52	20	48	31	31	41	12	44	43	94	9.22	−.3	24	10,636	s.	60	s.	6	2	10	19	7.8	0.0	0.0
Seattle	125	90	321	29.84	29.98	−.03	44.0	+2.3	58	19	48	31	31	40	15	42	39	83	5.41	−.2	21	8,284	se.	42	sw.	6	3	4	24	8.4	T	.0
Tatoosh Island	86	10	54	29.84	29.94	−.02	45.0	+1.1	53	18	48	33	31	42	10	43	40	85	11.05	−2.3	28	11,951	e.	59	s.	21	3	7	21	7.7	T	.0
Medford [1]	1,329	29	58	28.68	30.13		37.1		55	22	42	15	1	32	35	36	34	91	2.48	−.6	15		nw.				0	5	26	9.1	2.8	.0
Portland, Oreg	153	68	106	29.88	30.04	−.03	43.8	+2.6	58	18	47	27	1	40	15	42	40	87	8.28	+1.6	23	5,029	se.	21	s.	22	0	1	30	9.5	.5	.0
Roseburg	510	45	76	29.53	30.00	−.02	43.0	+1.2	63	22	50	28	3	36	24	41	39	84	3.16	−2.2	17	2,715	sw.	17	sw.	22	0	5	26	8.9	T	.0
Middle Pacific Coast Region							47.8	−0.2										72	3.78	−0.9										6.3		
Eureka	62	73	89	30.03	30.10	−.02	47.4	−.8	62	1	54	33	28	41	23	45	43	84	3.97	−2.3	13	4,534	se.	24	se.	26	2	8	21	7.4	.0	.0
Redding [1]	722	20	34				47.0	+.9	70	12	56	30	29	38	30	39	29	57	5.61	.0	9	5,083	nw.	23	n.	9	10	5	16	6.2	16.6	T
Sacramento	66	92	115	30.01	30.09	−.05	45.2	−1.0	64	8	53	31	4	37	31	42	36	72	2.62	−.4	9	4,372	se.	33	se.	26	10	8	13	5.6	.0	.0
San Francisco	155	112	132	29.89	30.06	−.06	51.6	+.3	67	10	57	40	31	46	18	47	43	77	2.94	−1.0	8	3,995	n.	26	sw.	26	8	9	14	6.1	.0	.0
South Pacific Coast Region							54.2	+1.2										68	4.73	+2.8										5.6		
Fresno	327	97	105	29.74	30.10	−.03	45.8	−.4	64	11	54	30	9	38	29	43	39	80	3.11	+1.7	9	3,729	e.	17	se.	30	11	3	17	6.3	.0	.0
Los Angeles	338	159	191	29.67	30.04	−.03	58.6	+2.0	79	22	67	39	30	50	28	49	40	58	6.63	+4.0	9	4,715	ne.	22	se.	27	15	6	10	4.5	.0	.0
San Diego	87	62	70	29.94	30.03	−.04	58.1	+2.1	78	19	66	45	5	50	26	51	44	67	4.45	+2.6	11	4,764	nw.	29	se.	27	12	5	14	5.9	.0	.0
West Indies																																
San Juan, P. R	82	9	54	29.88	29.97		75.8	−.5	85	17	80	68	27	71	14				9.87	+4.4	20	7,669	e.	34	ne.	27	7	19	5	5.1	.0	.0
Panama Canal																																
Balboa Heights	118	6	92		[3] 29.83	+.01	79.6	−.4	90	5	88	69	15	72	20			[2] 80	1.64	−2.4	12	4,277	nw.	20	n.	20	1	29	1	5.7	.0	.0
Cristobal	36	6	97		[3] 29.85	+.01	80.9	+1.0	88	5	86	73	13	76	12	75	73	[2] 78	3.53	−7.4	22	8,078	n.	27	ne.	10	14	15	2	4.1	.0	.0
Alaska																																
Fairbanks	454	11	87	29.30	29.89		−12.7		34	31	−6	−45	22	−19	33	−13	−15	86	1.12		11	2,879	w.	27	sw.	28	9	8	14	6.1	18.2	27.7
Juneau	80	96	116	[3] 29.61	[3] 29.70		27.8		44	9	31	10	5	24	15	26	21	74	9.11		25	6,701	s.	25	e.	3	5	5	21	7.8	43.2	9.5
Hawaiian Islands																																
Honolulu	38	86	100	[3] 30.00	[3] 30.04		72.4		79	7	76	62	29	69	12	65	61	68	3.16	−.8	24	9,769	e.	37	ne.	10	5	18	8	6.1	.0	.0

[1] Observations taken at airport.
[2] Observations taken bihourly.
[3] Pressure not reduced to 24-hour mean.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, December 1936*

Station	Altitude above mean sea level Jan. 1, 1919	Pressure: Station reduced to mean of 24 hours	Pressure: Sea level reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max.+mean min.÷2	Temperature of the air: Departure from normal	Temperature of the air: Mean maximum	Temperature of the air: Mean minimum	Temperature of the air: Highest	Temperature of the air: Lowest	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Total snowfall
	Feet	In.	In.	In.	° F.	° F.	° F.	° F.	° F.	° F.	In.	In.	In.
Cape Race, Newfoundland	99												
Sydney, Cape Breton Island	48												
Halifax, Nova Scotia	88												
Yarmouth, Nova Scotia	65												
Charlottetown, Prince Edward Island	38												
Chatham, New Brunswick	28	30.04									5.66	+2.44	32.5
Father Point, Quebec	20	30.13	30.16	+0.21	17.9	+2.5	27.6	8.2	49	−4	1.51	−1.32	13.4
Quebec, Quebec	296	29.82	30.17	+.16	19.2	+4.0	28.4	10.0	50	−8	3.55	−.14	11.3
Doucet, Quebec	1,236				15.1		22.0	8.3	49	−38	3.65		20.8
Montreal, Quebec	187												
Ottawa, Ontario	236	29.93	30.22	+.20	18.8	+1.8	28.0	9.6	48	−16	2.49	−.42	8.3
Kingston, Ontario	285												
Toronto, Ontario	379												
Cochrane, Ontario	930				10.6		21.8	−.5	46	−23	2.65		21.9
White River, Ontario	1,244												
London, Ontario	808												
Southampton, Ontario	656												
Parry Sound, Ontario	688												
Port Arthur, Ontario	644												
Winnipeg, Manitoba	760	29.16	30.04	+.02	9.7	+5.6	17.5	1.9	40	26	.75	−.16	7.5
Minnedosa, Manitoba	1,690												
Le Pas, Manitoba	860												
Qu'Appelle, Saskatchewan	2,115	27.60	29.96	−.04	8.6	+1.2	17.3	−.2	41	−35	1.07	+.55	10.5
Moose Jaw, Saskatchewan	1,759												
Swift Current, Saskatchewan	2,392												

TABLE 2.—*Data furnished by the Canadian Meteorological Service, December 1936*—Continued

Station	Altitude above mean sea level Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max.+mean min.÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*In.*	*In.*	*In.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*In.*	*In.*	*In.*
Medicine Hat, Alberta	2,365	27.41	30.00	+.03	14.2	−4.0	23.6	4.8	53	−31	1.22	+.67	12.2
Calgary, Alberta	3,540				16.1	−2.1	25.7	6.6	52	−22	.33	−.26	3.3
Banff, Alberta	4,521												
Prince Albert, Saskatchewan	1,450												
Battleford, Saskatchewan	1,592												
Edmonton, Alberta	2,150												
Kamloops, British Columbia	1,262												
Victoria, British Columbia	230												
Barkerville, British Columbia	4,180												
Estevan Point, British Columbia	20				41.5		46.4	36.6	53	28	14.46		.0
Prince Rupert, British Columbia	170												
St. Georges, Bermuda	158		30.19	+.07	67.3	+2.5	71.6	63.0	78	53	3.01	+1.90	.0
LATE REPORTS FOR NOVEMBER 1936													
Cape Race, Newfoundland	99				39.6		45.3	33.8	53	20	8.43		5.0
Sydney, Cape Breton Island	48	29.82	29.87	−0.08	37.7	+0.6	44.5	30.9	60	14	6.00	+0.56	2.5
Halifax, Nova Scotia	88	29.65	29.76	−.25	38.5	+1.2	44.7	32.3	60	7	4.46	−1.20	2.6
Yarmouth, Nova Scotia	65	29.81	29.88	−.14	39.6	−.3	46.2	32.9	58	12	3.21	−1.28	6.5
Charlottetown, Price Edward Island	38	29.81	29.85	−.11	34.6	−.9	41.3	27.9	60	5	4.65	+.68	9.1
Father Point, Quebec	20	29.86	29.89	−.07	23.9	−5.0	31.0	16.9	60	4	2.24	−.87	18.8
Quebec, Quebec	296	29.56	29.90	−.12	25.6	−3.4	31.2	20.0	62	−3	4.93	+1.17	23.9
Ottawa, Ontario	236	29.72	30.00	−.02	27.6	−4.1	35.0	20.2	65	−4	1.67	−.87	5.5
White River, Ontario	1,244	28.63	30.00	+.02	13.0	−7.5	24.4	1.7	41	−38	2.36	+.51	19.3
London, Ontario	808				31.8		39.4	24.3	62	−8	3.32		17.2
Parry Sound, Ontario	688	29.28	29.99	−.02	28.1	−4.0	36.2	20.0	61	−11	3.51	−.86	21.6
Winnipeg, Manitoba	760	29.24	30.11	+.07	21.0	+3.0	30.2	11.8	56	−7	1.09	+.01	9.1
Minnedosa, Manitoba	1,690	28.24	30.13	+.09	22.4	+5.1	31.7	13.2	55	−7	.23	−.77	2.3
Le Pas, Manitoba	860				20.0		29.7	10.3	50	−6	.96		8.6
Moose Jaw, Saskatchewan	1,759				30.2		40.4	20.1	72	−10	.32		3.2
Banff, Alberta	4,521	25.53	30.26	+.30	29.0	+3.2	30.7	18.4	59	−17	.24	−2.03	1.5
Battleford, Saskatchewan	1,592	28.36	30.17	+.15	27.4	+11.1	36.6	18.1	58	−13	.04	−.54	.4
Prince Rupert, British Columbia	170				44.1		49.0	39.2	55	28	10.65		.0

TABLE 3.—*Severe local storms, December 1936*

[Compiled by Mary O. Souder from reports submitted by Weather Bureau officials]

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A revised list of tornadoes will appear in the United States Meteorological Yearbook]

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks
Columbia, S. C	1	6 a. m.–11 p. m.				Glaze	Ice formed on branches, wires, and the northeast side of trees, poles, and houses. No glaze on streets and sidewalks. Several persons injured by falling.
Rochester, N. Y	2					Snow	7.5 inches of snow fell. No details.
Holland, Mich.,[1] vicinity of	5					Wind	After spending the night on a grounded steamer, 25 men were rescued by Coast Guardsmen.
Kalispell, Mont., and vicinity	5	10:45 a. m				Blizzard	Strong winds attended by rapidly falling temperatures and blowing snow. House demolished when a tree blew over.
Lincoln, Nebr	5					Rain and snow	Freezing rain and snow made streets and highways perilous. Wires were covered with sleet. Some roads were blocked until the 7th.
Iowa, northern portion	5–6			1		Blizzard	From 5 to 6 inches of snow recorded; roads slippery. Transportation services delayed; several persons injured.
Longview, Tex	6	3:30 a. m			$50,000	Tornadic winds	5 persons injured; property damaged.
Marshall, Tex	6	3:50 a. m			8,000	Tornado	4 persons injured; property damaged.
Greenville, Miss	6	7:15 a. m			50,000	do	Damage confined to 6 blocks in the business section; 4 persons injured.
Marlin, Tex	6	A. m			2,000	do	This small tornado caused damage to barns, outbuildings, and power lines.
Enon, Newala, and Spring Creek, Ala.	6	4 p. m	200		3,000	do	6 persons injured; property damaged; path 10 miles long.
Chilton County, Ala., southern portion.	6	6:30 p. m	200		15,000	do	10 persons injured; property damaged; path 4 miles long.
Olney, Mount Olive, Crumley's Chapel, Docena, and Hoagtown, Ala.	6		100–400	1	30,000	do	This tornado struck Olney at 12:30 p. m., Mount Olive at 2 p. m., and Crumley's Chapel and Hoagtown about 3:45 p. m.; 28 persons injured; property damaged over a path 30 miles long.
Havre, Mont	6–7					Snow	Depth of 17.5 inches recorded causing much difficulty and delay to transportation.
Rhode Island	12–13			2		Rain and ice	After 3 days of almost incessant rainfall, the Pautuxet River overflowed its banks in many places in the valley, bringing death to 2 pedestrians and injury to several persons and danger from rising waters and hazardous highway conditions throughout the State. Rain froze shortly before midnight of the 12th on the highways in the northern portion of the State. In the early morning of the 13th rain froze as it fell causing icy conditions on the State highways.
Lynchburg, Va	19	A. m				Glaze	¼ inch of glaze on wires, sidewalks, and other exposed objects.
Minnesota, extreme western counties.	19					Thick dust	This storm severe along the North Dakota border.
Geraldine, Mont., vicinity of	19					Wind and dust	Small damage to roofs and chimneys; an implement shed demolished. The wind, accompanied by intense dust clouds, reduced visibility to zero.
Erie, Pa	19					Wind	A maximum velocity 46 miles an hour recorded. Windows blown in, signs blown down, and roofs damaged.
Harrisburg, Pa	10					Glaze	Streets and sidewalks dangerously slippery during the afternoon and early evening resulting in several motor accidents.
Sonoma County, Calif., central portion.	26					High straight-line winds.	A person injured. Large water tank overturned; considerable damage to orchard and shade trees.
Iowa	26					Sleet, rain, and fog.	Slippery streets and highways.

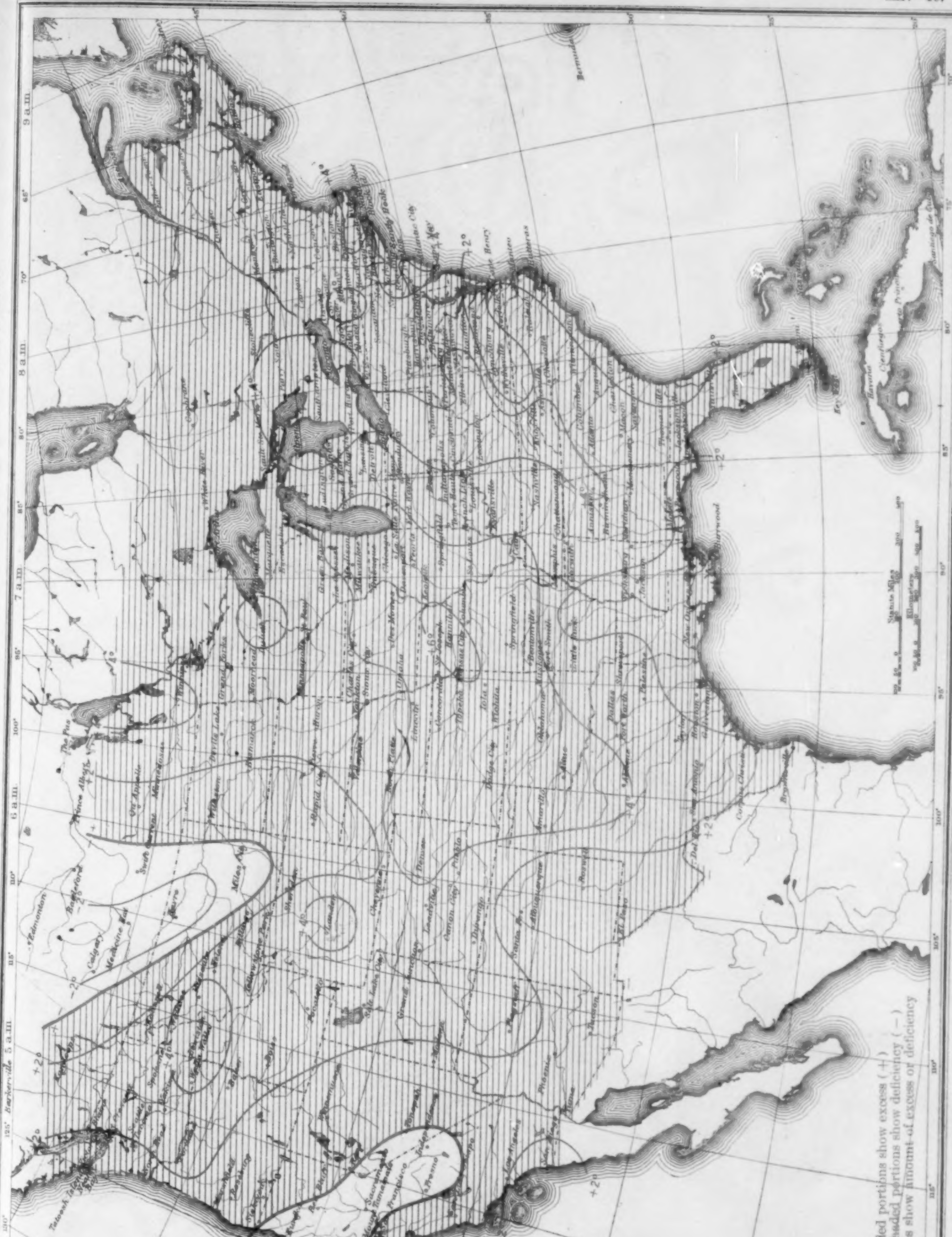
TABLE 3.—*Severe local storms, December 1936*—Continued

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks
South Dakota, northeastern portion.	26					Glaze	Telephone communication disrupted by broken wires and poles, principally in Sisseton and Peever, Roberts County. Ice 1 to 3 inches thick on wires. Highways slippery.
San Diego to San Francisco, Calif.	27	A. m.		1		Wind, rain, and snow.	Much loss to shipping industry in San Diego Harbor in the worst storm in years. Wind reached a velocity of 50 miles an hour; trees blown over and roofs blown off. The bay's shore line strewn with stranded and sunken small craft, demolished piers, and debris. In Long Beach store windows were broken and signs and trees blown down. Storm waters swept over the dike between National City and San Diego, making it necessary to reroute traffic. Heavy rains washed out a culvert near Ventura where 1.73 inches of rain fell.
Cimarron County, Okla	28-30				$375,000	Wind and heavy dust.	Heavy damage from blowing soils, it being estimated that 125,000 acres of wheat were destroyed; the money value given being the cost of labor and seeding the acreage destroyed.
Gunlock, Utah	28					Heavy snow	Power lines damaged.
Cass, Rock, Ringgold,[1] and Montgomery Counties, Iowa, and vicinity.	29-30					Snow, wind, electrical.	Farm houses and buildings damaged and roofs blown off. Large barn, 12 cattle, hay, and a milk house burned. Highways hazardous because of glaze under 3 inches of snow.
Beadle, Miner, Faulk, Sanborn, and Hamlin Counties, S. Dak.	29-31					Wind and glaze	Wires ice-coated as much as 1½ inches thick; telephone and power service disrupted; highways very slippery.
Mountain View, Ark	30				500	Electrical	Property damage.
Illinois	30				9,100	Thundersqualls	These storms prevailed over practically the entire State. Property damage reported at Cambridge, Princeton, and Freeport. At Golden and Paw Paw loss unestimated, but little damage to trees and buildings.
Marysville to Oketo, Kans	30	1 a. m.	440-1,760		10,000	Wind	This storm had tornadic characteristics. 2 persons injured; large number of farm buildings wrecked or damaged; path 9 miles long.
Springfield, Jefferson City, Pleasant Hope, Fulton, Mo., and vicinity.	30				500	do	These small storms had tornadic characteristics. Damage mostly to outbuildings and porches.
Pryor, Okla	30	5 a. m.			10,000	do	Property damage.
Nashville, Tenn	30					Wind and rain	Electric service interrupted and basements flooded.
Green and Rock Counties, Wis.	30				10,000	Windsqualls	Small buildings demolished and several barns damaged.
Gunlock, Utah	31					Heavysnow	Highways blocked.
LATE REPORT FOR NOVEMBER 1936							
Templeton, Fla., vicinity of	5		67-100		$800	Small tornado	Fruit, amounting to about 2,000 boxes, blown from trees; 24 trees uprooted; path 2 miles long.

[1] From press reports.

Chart I. Departure (°F.) of the Mean Temperature from the Normal, December 1936

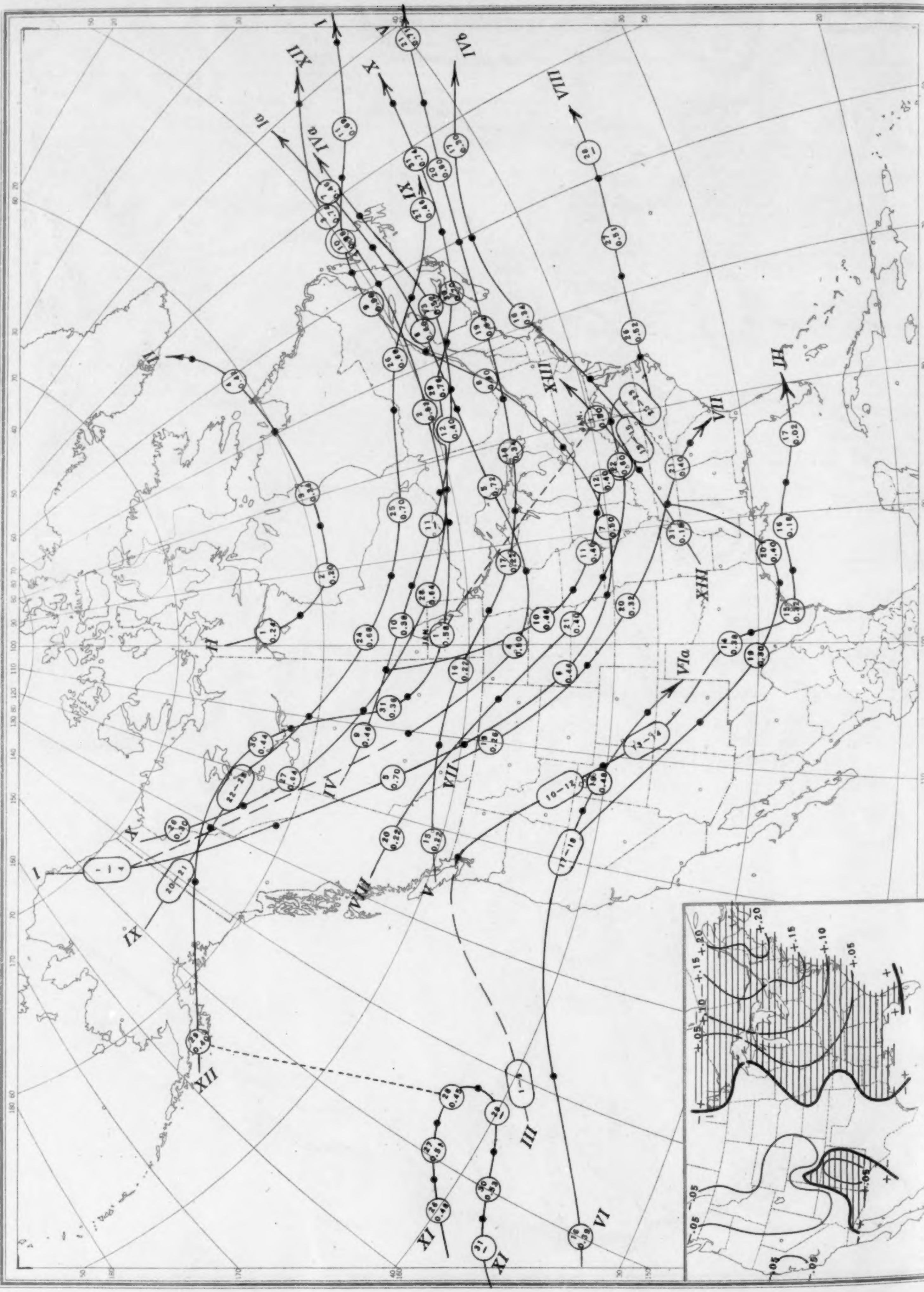
Chart I. Departure (°F.) of the Mean Temperature from the Normal, December 1936



Shaded portions show excess (+)
Unshaded portions show deficiency (−)
Lines show amount of excess or deficiency

Chart II. Tracks of Centers of Anticyclones, December 1936. (Inset) Departure of Monthly Mean Pressure from Normal

(Plotted by W. P. Day)

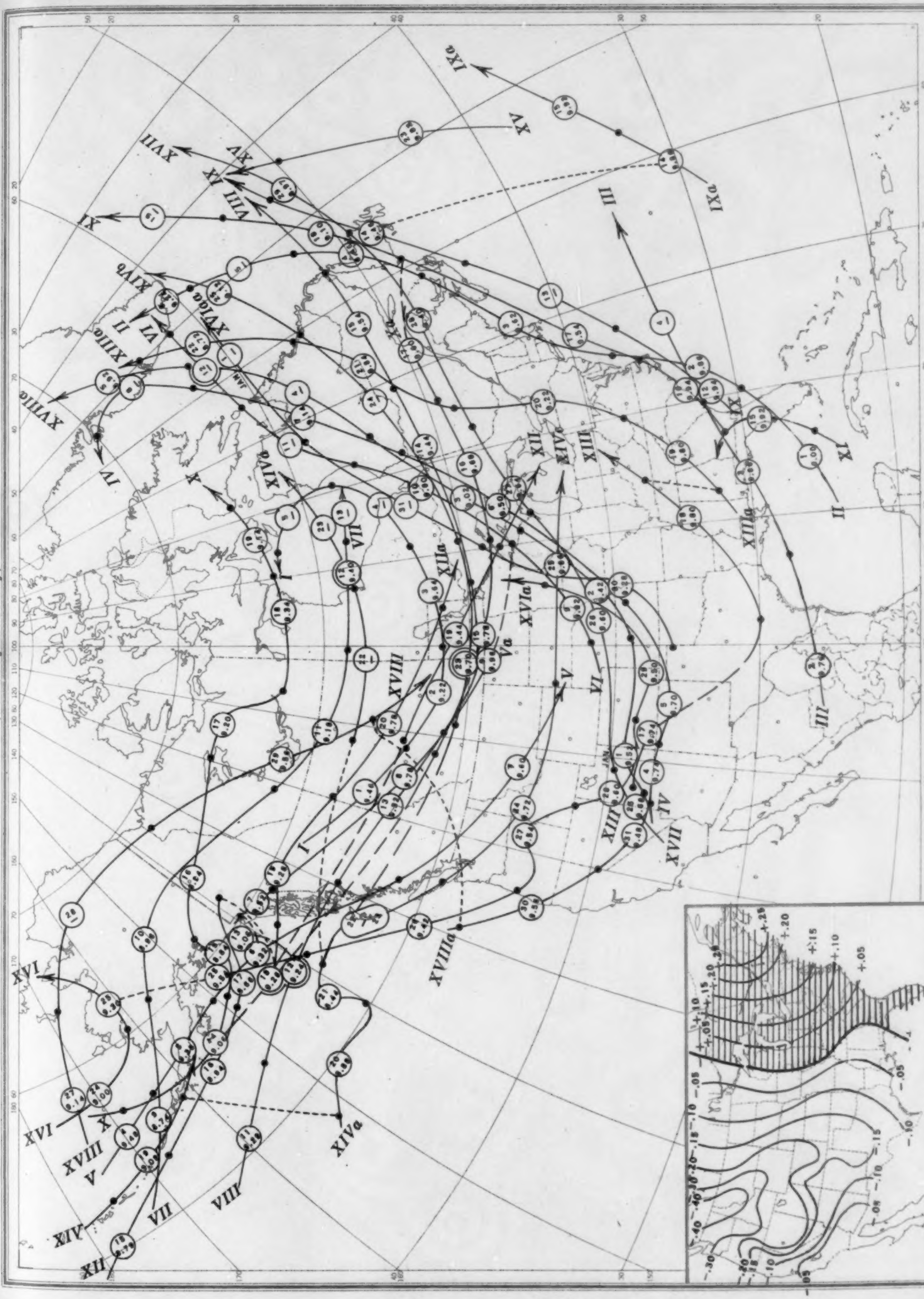


Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

Chart III. Tracks of Centers of Cyclones, December 1936. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by W. P. Day)

Chart III. Tracks of Centers of Cyclones, December 1936. (Inset) Change in Mean Pressure from Preceding Month
(Plotted by W. P. Day)



Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky Between Sunrise and Sunset, December 1936

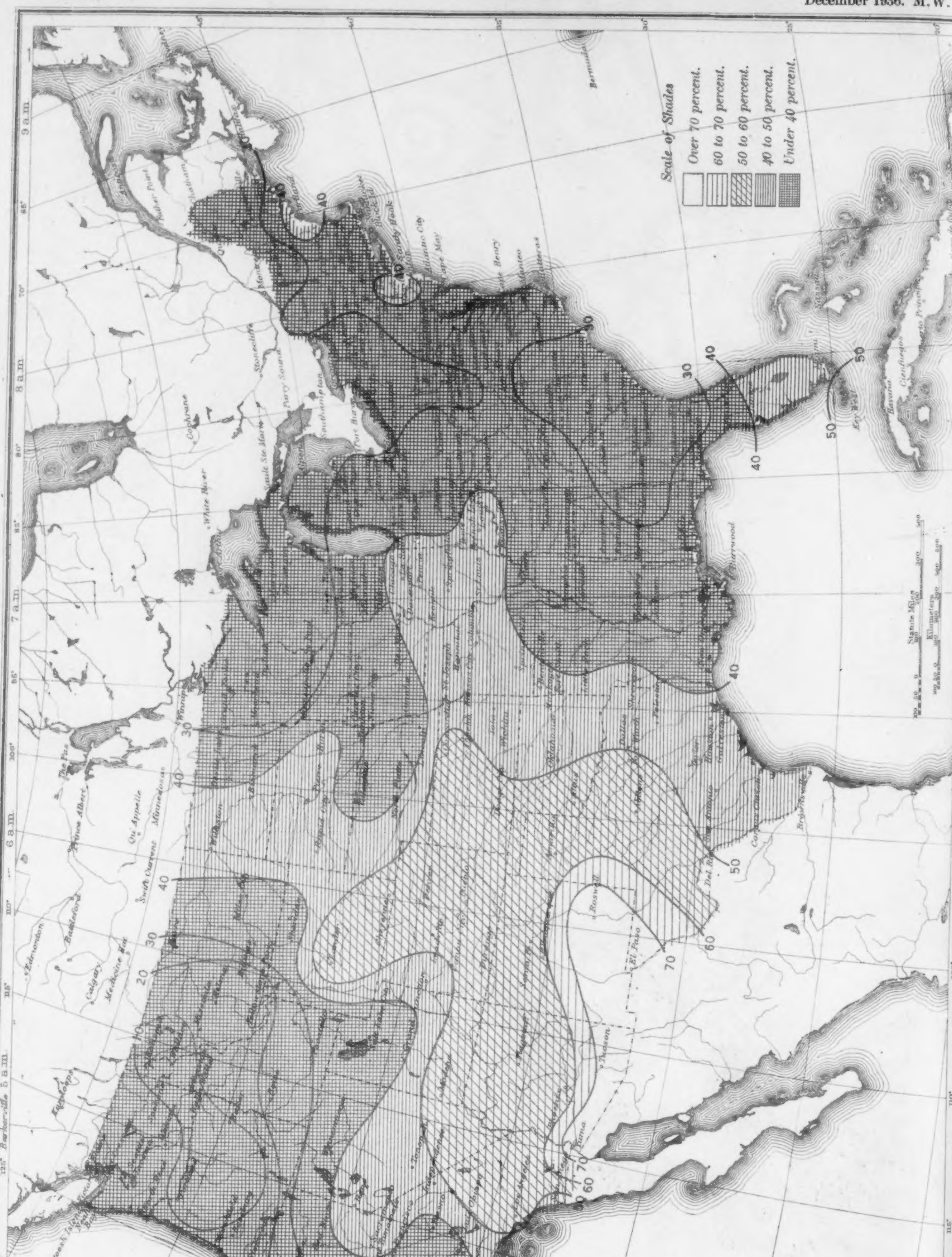


Chart V. Total Precipitation, Inches, December 1936. (Inset) Departure of Precipitation from Normal

Chart V. Total Precipitation, Inches, December 1936. (Inset) Departure of Precipitation from Normal

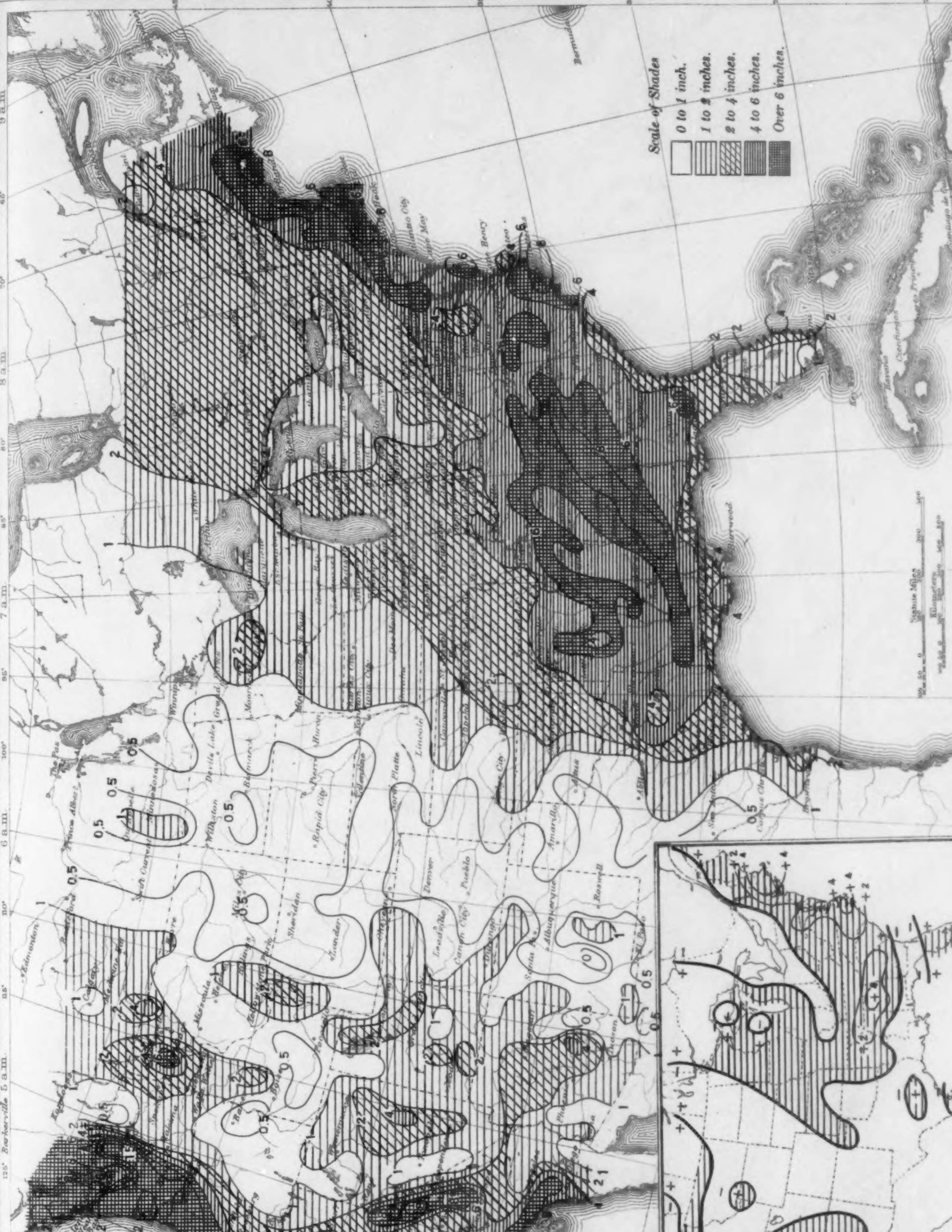


Chart VI. Isobars at Sea Level and Isotherms at Surface; Prevailing Winds, December 1936

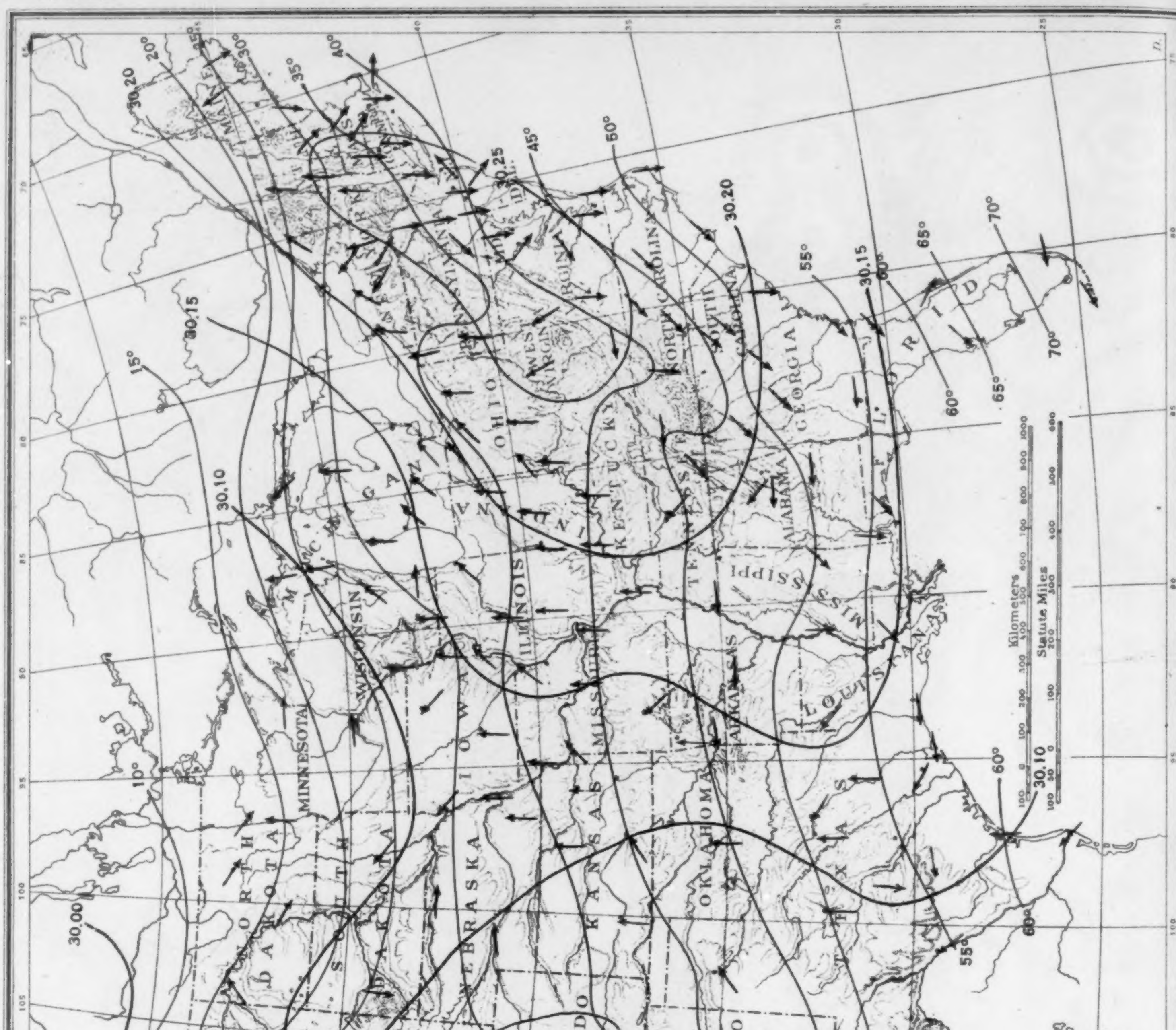


Chart VII. Wind Roses for Selected Stations, December 1936
(Plotted by W. W. Reed)

Chart VIII. Total Snowfall, Inches, December 1936. (Inset) Depth of Snow on Ground at 8 p.m., Monday, December 28, 1936

Chart IX. Weather Map of North Atlantic Ocean, December 3, 1936
(Plotted from the Weather Bureau Northern Hemisphere Chart)

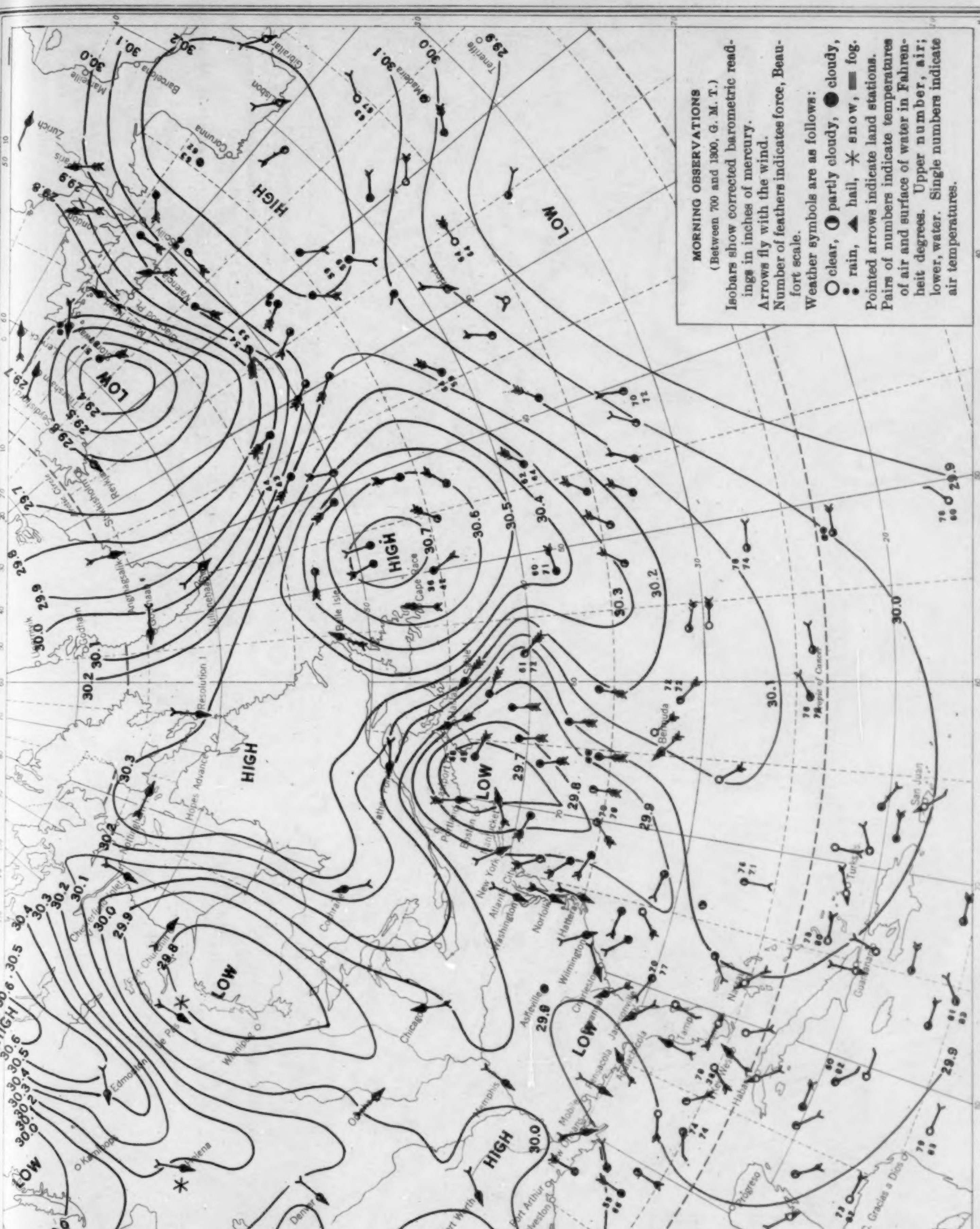


Chart IX. Weather Map of North Atlantic Ocean, December 5, 1936
(Plotted from the Weather Bureau Northern Hemisphere Chart)

Chart X. Weather Map of North Atlantic Ocean, December 7, 1936

(Plotted from the Weather Bureau Northern Hemisphere Chart)

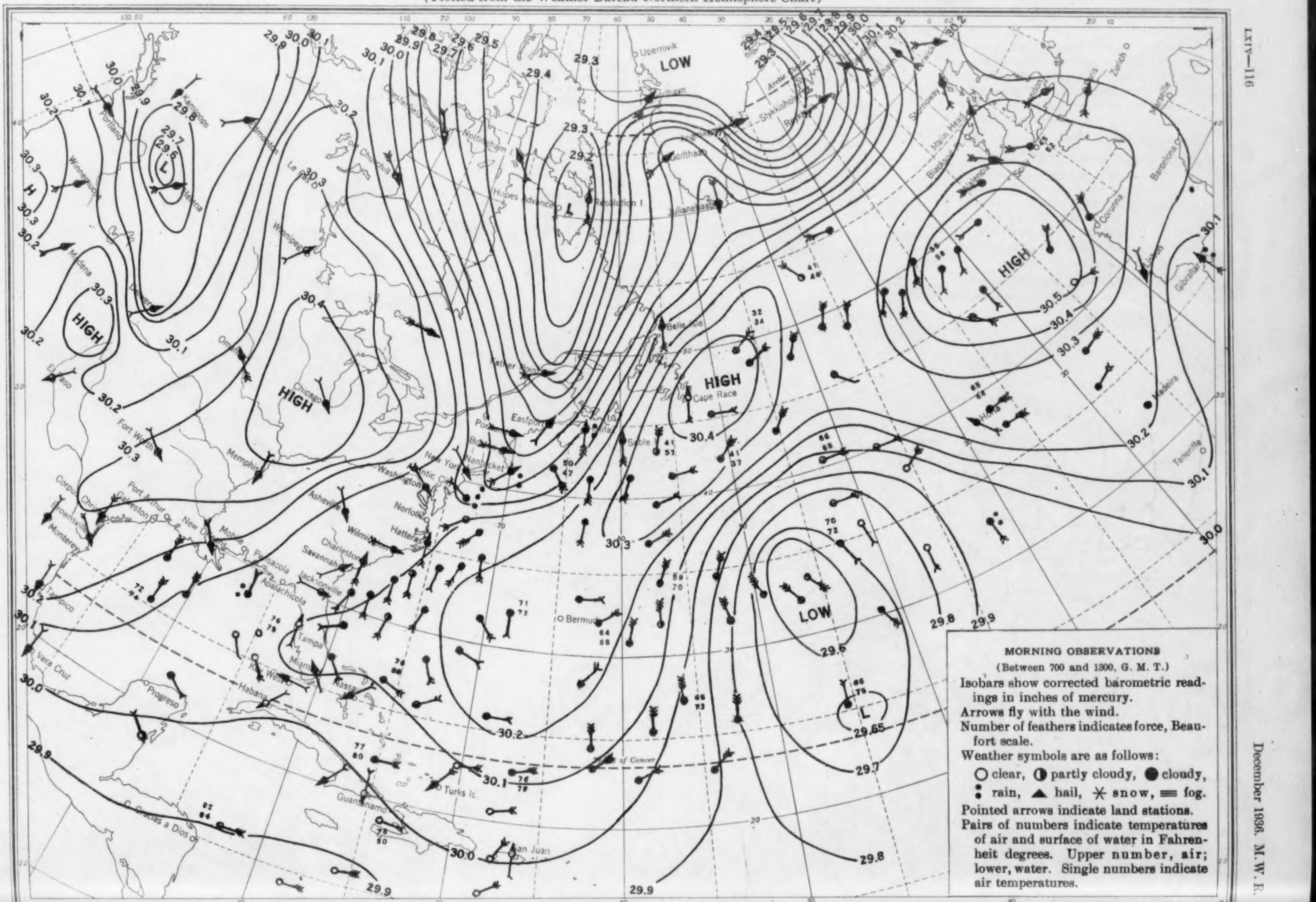
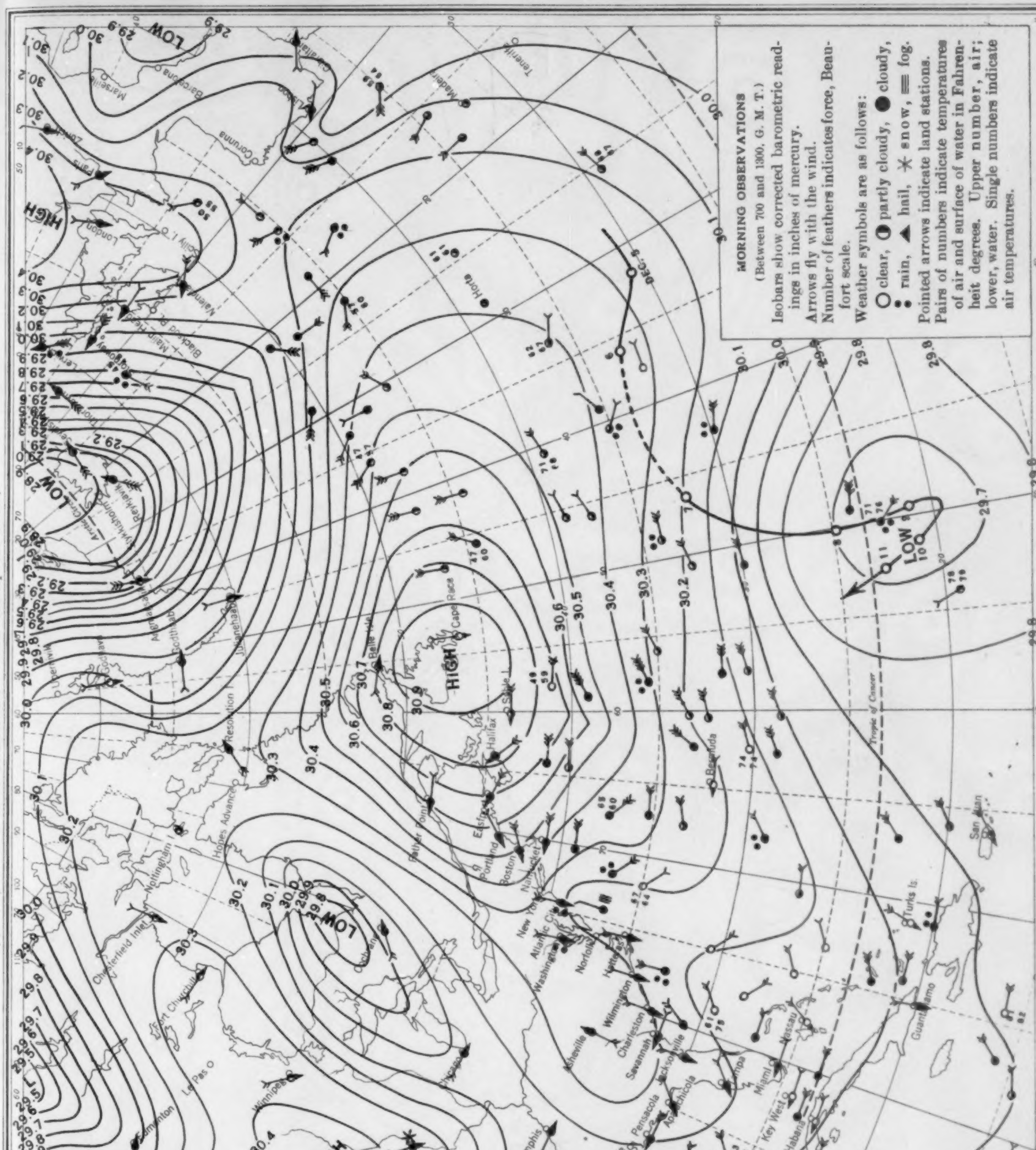


Chart XI. Weather Map of North Atlantic Ocean, December 10, 1936

Chart XI. Weather Map of North Atlantic Ocean, December 10, 1936
(Plotted from the Weather Bureau Northern Hemisphere Chart)



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